BIG CREEK HYDROELECTRIC SYSTEM, POWERHOUSE 2 AND 2A
(Big Creek No. 2/2A)
South Bank of Big Creek, approximately 3.5 miles west of Big Creek
Big Creek vicinity
Fresno County
California

HAER CA-167-F
HAER CA-167-F

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

FIELD RECORDS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C Street NW
Washington, DC 20240-0001

HISTORIC AMERICAN ENGINEERING RECORD

BIG CREEK HYDROELECTRIC SYSTEM, POWERHOUSE 2 AND 2A
(Big Creek No. 2/2A)

HAER No. CA-167-F

LOCATION: South bank of Big Creek, approximately 3.5 miles west of Big Creek
Big Creek vicinity, Fresno County, California

STRUCTURAL TYPE: Reinforced concrete and steel power generation building

DATE OF CONSTRUCTION: 1913, 1928

DESIGNER: Stone and Webster Engineering Corporation

BUILDER: Stone and Webster Engineering Corporation

PRESENT OWNER: Southern California Edison, Northern Hydro Division

PRESENT USE: Hydroelectric generation facility

SIGNIFICANCE: Constructed in 1913, Powerhouse 2 was part of the initial phase of the pioneering Big Creek development of the Pacific Light and Power Corporation. At the time of its construction Powerhouse 2, along with its twin, Powerhouse 1, was one of the highest-head hydroelectric developments in the West. The waterwheels and generators were among the largest of their type ever constructed, and the system was the first in the world to transmit electricity commercially at 150 kilovolts (kV).

Powerhouse 2A was completed in 1928 and is joined to Powerhouse 2. The two generating units of Powerhouse 2A were the largest of their type in the world at the time of their construction, and the plant utilizes one of the highest heads in the western United States.

The Big Creek system was the premiere example of the transition from the construction of isolated power plants serving local markets to the construction of large systems integrated with distant energy markets via high-voltage transmission. Powerhouse 2, as one of the first two plants in the system, is especially symbolic in this regard.

The Big Creek system is also significant in the history of the Los Angeles region. Conceived as a means of powering both residential development and electric railways, power from Southern California Edison's Big Creek plants was instrumental in the rise of suburban development in the region. The system is closely associated with railroad, energy, and development magnate Henry Huntington; with Edison executives and power pioneers A.C. Balch, William Kerckhoff, and George C. Ward; visionary California hydroelectric engineer John Eastwood; and longtime Big Creek manager David Redinger.

HISTORIAN: Daniel Shoup, PhD
Archaeological/Historical Consultants, Oakland, California

PROJECT INFORMATION: The research for this report was sponsored by Southern California Edison Corporation as part of the HAER documentation of Big Creek Powerhouses 1, 2/2A, 3, and 8 and Operator's Cottage 115. Historical narratives were written by Daniel Shoup of Archaeological/Historical Consultants (Oakland, California) with contributions from Geoff Goodman. Historical research was conducted between September and December 2009 by Laurence Shoup, Suzanne Baker, Geoff Goodman, and Daniel Shoup of Archaeological/Historical Consultants. HAER photography was produced by David De Vries and Marissa Rocke of Mesa Technical (Berkeley, California) between September 2009 and January 2010. Administrative and research support was provided by Don Dukleth of Southern California Edison, Northern Hydro Division (Big Creek, California), and Thomas T. Taylor of Southern California Edison, Corporate Environment, Health, and Safety (Rosemead, California). NERC CIP compliance review was conducted by Ahmad Sanati and Sooraj Sadanandan of Southern California Edison, Power Production Department (Rosemead, California).

This report is presented as one of a series of HAER reports on the early Big Creek powerhouses, including Powerhouses 1, 2/2A, 3, and 8, and Operator's Cottage 115. These studies focus on the period from 1912, when construction began, to 1929, the end of the "great expansion" of the Big Creek system. Previous research has identified 1912-1929 as the period of significance for the system as a whole.

This study focuses on the history of the powerhouse structure itself. Other features of the Big Creek system, such as dams, tunnels, penstocks, residences, forebays, outdoor substations, and power lines are not treated in detail. Similarly, the social history of Big Creek town and other communities in the vicinity are touched on only briefly in this text.

Many publications and technical reports offer more detail on the Big Creek system. Former Big Creek superintendent David Redinger's *The*

Story of Big Creek remains a key reference work.[1] Other important works include historic studies and significance evaluations of the system and the town, one of which is appended as Field Notes to CA-167-E.[2] Previous HAER reports on parts of the Big Creek system were also prepared by Thomas T. Taylor of Southern California Edison.

HAER reports for the Big Creek System prepared to date include:

- Operator Cottage, Big Creek # 8 (HAER CA-167-A)
- Big Creek #3 penstock standpipes (HAER CA-167-B)
- Operator Cottage 105, Big Creek Town (HAER CA-167-C)
- Operator House Garage, Big Creek Town (HAER CA-167-D)
- Big Creek Powerhouse 1 (HAER CA-167-E)
- Big Creek Powerhouse 2/2A (HAER CA-167-F)
- Big Creek Powerhouse 8 (HAER CA-167-G)
- Big Creek Powerhouse 3 (HAER CA-167-H)
- Operator Cottage 115, Big Creek Town (HAER CA-167-I)

See the bibliography for this report and the other reports in the series for more complete references. Copies of historic photographs have been included in the field records accompanying this documentation.

[1] David H. Redinger, *The Story of Big Creek* (Los Angeles: Angelus Press, 1949).
[2] Laurence H. Shoup, *"The Hardest Working Water in the World": A History and Significance Evaluation of the Big Creek Hydroelectric System*, Southern California Edison Company, Rosemead, CA, 1987; Laurence H. Shoup, *Life at Big Creek Town 1929-1947: Historic Context Statement and National Register of Historic Places Significance Evaluation*, Southern California Edison Company, Rosemead, CA, 1997.

STYLE, DESIGN, AND CONSTRUCTION

Setting and Style

Powerhouses 2 and 2A consist of two hydroelectric generation buildings with six generating units, connected by a central corridor. Powerhouse 2 is a five-story reinforced concrete and structural steel building 104' high. It measured 171' x 85' on initial construction in 1913 and 227' x 85' after its expansion in 1921. Powerhouse 2A measures 210' long, 66' wide, and 60' high. The powerhouse buildings are located on the south bank of Big Creek, approximately 3.5 miles west of Big Creek town. Viewed from the north, the buildings rise directly from the creek with, forested hills rising steeply behind them. Besides the visible line of the penstocks, little other development is evident in the vicinity.

The architecture of Powerhouse 2 blends industrial modern and neoclassical styles to express a mix of formalism and functionalism. American industrial architecture of the early twentieth century favored the derivation of architectural form from the frame of the structure, leading to a 'façade grid' elaborated from the alternation of vertical structural supports and horizontal floors. In designing façade details, however, architects often decorated this basic grid with elements derived from formalist styles such as gothic revival or neoclassicism.[3]

In the case of Powerhouse 2, the columns of the structural frame are elaborated into pilasters on the façade, establishing strong vertical lines. Between each pilaster is a bay with window openings corresponding to the floors of the building. On the lower floors windows are separated by recessed, undecorated spandrels. Between the fourth and fifth floor a stringcourse with pendant dentils separates the windows. Above the fifth floor, the pilasters are topped with an undecorated, projecting frieze and projecting cornice. On the east and west ends of the buildings, the roof peaks to form an undecorated gable with massive cornice. On the south side of the building at the first, second, and fifth floors, undecorated recessed spandrels occupy the locations of the windows on the other sides of the building, while a canopy projects from the fifth floor. Views CA-167-F-3 through CA-167-F-8 show external elevations of the structure in late 2009.

The combination of the evenly spaced pilasters with the dentils and the gabled roof suggests neoclassical influences on the part of Stone and Webster's architects. The use of neoclassical elements in public utility architecture was common in California in the period 1900-1915. Well-known examples include the designs of Willis Polk for Burnham and Root's San Francisco Office, including Pacific Gas and Electric Company's Jessie Street Substation in San Francisco and the San Francisco Water District's Sunol Water Temple marking the end of the Hetch Hetchy Aqueduct.[4] Compared to these examples of highly elaborated neoclassicism, however, the approach at Powerhouse 1 is much more restrained and functionalist.

Although Powerhouse 2 is a well-preserved example of important trends in American industrial and public utility architecture, it cannot be said to be a uniquely significant example of its

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[3] Betsy Hunter Bradley, *The Works: Industrial Architecture of the United States* (New York: Oxford University Press, 1999), 231.
[4] Harold Kirker, *California's Architectural Frontier: Style and Tradition in the 19th Century* (San Marino, CA: Huntington Library, 1960), 115ff.

architectural style or building type. Rather, the significance of Powerhouse 2 lies in its excellent state of preservation and in its role as part of a pioneering large integrated system of electrical generating plants. As Duncan Hay notes of contemporary hydroelectric systems more generally,

> individual structures and pieces of hardware were seldom significant in and of themselves. Their importance lay in their role within complete powerplants and, in some cases, within basin-wide or regional developments.[5]

The Big Creek system remains one of the most significant hydroelectric generation and transmission systems in California and western North America.

Powerhouse 2A appears to have been designed to match the adjacent Powerhouse 2 in style. It follows its predecessor in embracing a mixture of functionalism and formalism. While the façade suggests the Colonial Revival style, embellishment is restrained and the formal details, such as the gable and pilasters, follow the structural frame of the building. The reduced height of Powerhouse 2A compared to Powerhouses 1 and 2 reflects the fact that busses and transformers were located on an open porch, or outdoors on an adjacent platform. Experimentation with outdoor bussing and switching was ongoing in the 1920s, and powerhouse designers discovered that generating buildings could be made shorter and architecturally simpler by removing this equipment from the plant and placing it outside.[6] The architectural solution for Powerhouse 2A was, in a sense, less progressive than that at Powerhouse 3 (1923), which featured a fully outdoor switchyard in its original construction. View CA-167-F-27 shows a context view of Powerhouse 2A and Views CA-167-F-28 through CA-167-F-31 show details of the external elevations.

Powerhouse 2/2A contains a total of six generating units. Originally the units in Powerhouse 2 were numbered 1 through 4. When Powerhouse 2A was constructed, the units were initially numbered 1 and 2. Presumably to reduce confusion with Units 1 and 2 in Powerhouse 2, these were later referred to as Units 5 and 6. Around 1930 the whole numerical order was reversed, and the numbering system currently in use by Southern California Edison was adopted: Units 1 and 2 are located in Powerhouse 2A, while Units 3, 4, 5, and 6 are in Powerhouse 2.

For clarity, this report uses the numbering system currently in use by Southern California Edison to describe the generating equipment. The reader should bear in mind, however, that Units 3 and 4 (installed 1913) are the oldest in the powerhouses, followed by 5 (1921), 6 (1925), 1 (1928) and 2 (1928). Caution should be taken if primary or secondary sources are consulted, since they may refer to older numbering systems.

Designing Engineer

John S. Eastwood

The Big Creek system was the brainchild of engineer John Eastwood (1857-1924), who identified the Big Creek and San Joaquin River systems as an ideal location for a series of storage reservoirs and power plants. Between 1902 and 1910, Eastwood worked for Pacific Light

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[5] Duncan Hay, *Hydroelectric Development in the United States, 1880-1940* (Washington, D.C.: Edison Electric Institute, 1991), 28.

[6] "High Head and Large Units at Big Creek 2-A," *Electrical West*, November 17, 1928, 991.

and Power Corporation designing the project. He conducted the preliminary surveys, planned the powerhouse, secured water rights, and applied for permits from the US Department of Agriculture. Despite his instrumental role in designing the project, Eastwood did not play a role in the construction of the Big Creek powerhouses.[7]

Architects, Contractors, and Constructing Engineers

Stone and Webster Construction Company

Pacific Light and Power hired Stone and Webster Construction Company of Boston, Massachusetts, to design the powerhouses and manage construction of the system. Stone and Webster, founded in 1890, became a major designer and builder of transportation and hydroelectric systems by 1900. It built some of the world's largest hydroelectric projects in the first decades of the twentieth century, including Keokuk, Iowa (1913, 124,800 kilowatts [kW]), Big Creek (1913, 147,000 kW), and Conowingo, Maryland (1928, 252,000 kW).[8] Stone and Webster also managed a wide array of utility companies throughout the United States.[9]

The architect or architects of Powerhouses 1 and 2 and the very similarly-styled Eagle Rock substation in Los Angeles are unknown. Stone and Webster had established a drafting and management office for the Big Creek project in Fresno, and it is possible that powerhouse design work took place there.[10] The overall construction was supervised by S.L. Shuffleton, the western manager for Stone and Webster, who was based in Seattle and visited the project only occasionally.[11]

Other Contractors

Several other contractors were known to have been on site during construction of Powerhouse 2. Two representatives of the penstock manufacturer, Mannesman Rohrenwerke of Düsseldorf, Germany, were sent by the factory to "represent the company and be of possible assistance in laying the pipe."[12] The roof of Powerhouse 2 was installed by the Paraffine Paint Company of San Francisco.[13]

Southern California Edison Construction Department

Powerhouse 2A was designed and built in 1927 and 1928 by the Construction Department of Southern California Edison Company, Limited. Known contractors on the construction job included the Faris-Osborne Company of Fresno, California, which installed the roofing, and Continental Building Specialties of San Francisco, which placed the floors in the plant.

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[7] See Redinger, *Story of Big Creek*, 4-7; Charles A. Whitney, "John Eastwood: Unsung Genius of the Drawing Board," *Montana: The Magazine of Western History*, Summer 1969, 38-48; Shoup, *Hardest Working Water*, 55-63.
[8] Hay, *Hydroelectric Development*, 101.
[9] Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983), 388.
[10] "Big Creek Work Nears Completion," *Fresno Morning Republican*, December 2, 1913.
[11] Redinger, *Story of Big Creek*, 34.
[12] Redinger, *Story of Big Creek*, 33.
[13] Arthur R. Kelley, *Unit Cost Development Accompanying Valuation of Electric Properties, Southern California Edison Big Creek No. 2 Development, Including Huntington Lake Reservoir, December 31, 1922*, Federal Project 67 Appendices, Plant Accounting Department, Southern California Edison Company, Rosemead, CA, 25.

Representatives of several suppliers, including Pelton, Allis-Chalmers, General Electric, and Westinghouse were known to have been on site as consultants during construction.

Suppliers

Mannesman Rohrenwerke of Düsseldorf, Germany supplied the penstocks for Units 3 and 4 in Powerhouse 2, while the M.W. Kellogg Company supplied those for Unit 5.[14] The turbines for Units 3 and 4 were manufactured by the Allis-Chalmers division of the I.P. Morris Company of Milwaukee, Wisconsin. Unit 5 was supplied by Pelton Water Wheel of San Francisco. Generators, transformers, and electrical equipment were supplied by the Westinghouse Company. Steel for the structural frame was procured from Bethlehem Steel, with "fabrication at West Coast plants," possibly including their Union Iron Works facility in San Francisco. The roof trusses and canopy steel were manufactured by the Llewellyn Iron Works of Los Angeles.[15] Replacement roof trusses after the fire of October 1913 were purchased from the Union Iron Works in San Francisco, California.[16] The remainder of the steel used in the plant came from Judson Manufacturing Company (Oakland, CA), Baker Iron Works (Los Angeles, CA), Pacific Rolling Mills and Brode Iron Works (San Francisco, CA), Phoenix Iron Works (Boston, MA), and Des Moines Bridge and Iron (Pittsburgh, PA).[17] Five-ply Barrett Roofing was used to waterproof the roof of the structure.[18] The traveling crane in the generator room was supplied by Cleveland Electric Company.[19]

Steel for the Powerhouse 2A penstocks was purchased from the Ferrum Company (Katowice, Poland), Midvale Iron and Steel (Nicetown, Pennsylvania), and Bethlehem Steel (Bethlehem, Pennsylvania). Midvale Iron and Steel was, at this date, a subsidiary of Bethlehem Steel.[20] The waterwheels for Unit 1 were supplied by Allis-Chalmers Company of Milwaukee, Wisconsin, and those for Unit 2 by the Pelton Waterwheel Company of San Francisco, California. The generators for both units were supplied by Westinghouse and manufactured in East Pittsburgh, Pennsylvania, while General Electric furnished the transformers and circuit breakers. Steel for the building frame was purchased from the McClintic-Marshall Company, Watts, California, and the roofing was Pabco brand, installed by the Faris-Osborne Company of Fresno, California. Floors were placed by Continental Building Specialties Company, and Fuller brand paints were used throughout the plant. Lumber for the window sash and doors was supplied by the L.W. Blinn Lumber Co., Los Angeles. The traveling cranes were purchased from Western Manning, Maxwell, and Moore Incorporated of Muskegon, Michigan.[21]

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[14] Walter Jessup, "A High-head Hydroelectric Power Development in the Sierra Nevada Mountains, California," *The Wisconsin Engineer* 18 (1914): 200; Arthur R. Kelley, *Valuation of Electric Properties, Southern California Edison Big Creek No. 2 Development, Including Huntington Lake Reservoir, December 31, 1922*, Federal Project 67 Appendices, Plant Accounting Department, Southern California Edison Company, Rosemead, CA, 133.
[15] Kelley, *Unit Cost Development*, 10, 11.
[16] Kelley, *Unit Cost Development*, 9.
[17] Kelley, *Unit Cost Development*, 8.
[18] Kelley, *Unit Cost Development*, 25.
[19] Kelley, *Unit Cost Development*, 32.
[20] "New Big Creek Unit Penstock Contracts Let By Edison," *Journal of Electricity*, October 1, 1926, 258.
[21] Arthur R. Kelley, *Unit Cost Report, Big Creek No. 2A Development, as of December 31, 1932*, Federal Project 67 Appendices, Plant Accounting Department, Southern California Edison Company, Rosemead, CA, 38, 39, 43, 58, 86-90, 98-100.

Construction Narrative

Powerhouse 2
The Big Creek development began in November 1911. After completion of the San Joaquin and Eastern Railroad in July 1912, excavation work began for Powerhouses 1 and 2, which were constructed simultaneously. By the end of 1912, foundation excavation for Powerhouse 2 was well underway, and the foundation of the building had been poured by May 1913.[22] The plant was almost complete when a fire damaged the building on October 17, 1913. After repairs, the first unit (Unit 3) was started up on December 18, 1913, and the second unit (Unit 4) several days later.[23] Unit 5, of similar design to Units 3 and 4, was constructed between January 1920 and February 1921.[24] The plant was expanded by 56' to accommodate the installation of Unit 6 in April 1925.[25]

Powerhouse 2A
For Powerhouse 2A, construction details are available in the *Weekly Letter Reports* filed by the chief operator of Powerhouse 2 during the period of construction. These allow us to understand the construction of the plant in detail.[26]

Foundations: excavation and construction
Excavation for Powerhouse 2A began on August 6, 1926 and continued until mid-March of the following year. Two shifts of men each day worked clearing Big Creek of rock and blasting until bedrock was reached. Between October 9 and November 20, a coffer dam was built to divert water from the power plant site.[27] On March 26, 1927, workers began constructing the forms for the foundation of Powerhouse 2A, and began pouring concrete on April 9. Foundation pouring continued to mid-July. An improvised solution had to be used for the foundation of Unit 1, as the July 16 Weekly Report noted: "good rock was not reached in the base of the Allis Chalmers unit [Unit 1], so a five foot slab of concrete, tied together with rail-road iron, was poured over the whole pit."[28]

Bridge construction
Construction began on the steel bridge that would carry a railroad line into Powerhouses 2 and 2A on March 12, 1927, when the concrete anchors were poured. Work continued into August, requiring Dam #5 to be held down at intervals to allow completion of the concrete piers. On August 20, the first steel for the bridge trusses arrived on site. The steel members were laid in

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[22] Stone and Webster Construction Company, "Progress of the Big Creek Initial Development: Report to Pacific Light and Power Corporation, January 1, 1913," 3, in Water Resources Library, University of California, Berkeley.
[23] Kelley, *Valuation*, 4; Southern California Edison, "Memorandum, Hydro Generation, Northern Division, Generator Winding Data Revised to May 13, 1985," 2, in History and Information File, Northern Hydro Division Headquarters Library, Big Creek, California.
[24] Kelley, *Valuation*, 5.
[25] "Big Creek No. 2 Power House Being Extended 56 ft." *Journal of Electricity* 54 (1925): 212.
[26] Southern California Edison Company, *1926 Weekly Letter Reports, Big Creek Powerhouse 2*, *1927 Weekly Letter Reports, Big Creek Powerhouse 2*, and *1928 Weekly Letter Reports, Big Creek Powerhouse 2*, all in Archive Room, Big Creek Powerhouse 2/2A, Big Creek, CA.
[27] Southern California Edison, *1926 Weekly Letter Reports.*
[28] Southern California Edison, *1927 Weekly Letter Reports.*

October, with completion on October 22. In early November, forms for the concrete bridge surface were set up. The bridge was completed shortly thereafter.[29]

Powerhouse 2A structure

Work on the powerhouse structure began in early July 1927. In the week of July 2, the floor slab of the transformer deck was poured, while two crews worked on the generator pits. The first concrete was poured in the bases of the new units on July 16. In the week of July 23, work started on the excavation of the piers for the 220kV switch deck, a slab supported on piers above the forebay adjacent to the tailrace exits. Concrete work was completed to the level of the generator floor by July 30.

Steel for the building began to arrive on August 20. As the Weekly Letter Report for that week noted, "Construction Dept. men are putting slings on fifth floor at the east end of the [Powerhouse 2] building, for the purpose of drifting steelwork into place for PH2A. 150 K.V. busses changed from the 5th to the 4th floor for this purpose."[30]

Steel was drifted into place from late August. The Weekly Letter Report for September 24 reported that "the steel framework for Powerhouse 2A is practically completed, and staging is being erected for the form work for the walls etc." Other work in the late summer included the concrete for the 220kV oil switch platform and the lining of the generator pits, which used a layer of tar paper between concrete slabs.[31]

Formwork for the walls was completed by the middle of October, when construction crews began pouring concrete for the walls. By the end of October, the concrete and form work for the switch room, generator pits, and wheel pits was nearly complete.

By November 19, the framework for the new building had been complete to the level of the crane rails. Parts of the cranes had by that time arrived, and workers hastened to assemble the crane girders. By November 3 "one of the new cranes has been completely assembled and is being connected up so that the crane may be moved to facilitate the erection of the second crane." In addition, "the form work for the walls is now completed and approximately 25% of the roof has been covered to date."[32]

The upper parts of the wall were being poured in the first week of December, 1927, while the formwork on the lower part of the building was stripped off. On December 17 the formwork for the roof was complete and both cranes were erected and operational. Pouring the roof continued, and by the end of the year the roof was almost complete. The interior formwork was removed in the week of December 31, 1927, while the roof and cornice forms were removed in the week of January 14, 1928.

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[29] Southern California Edison, *1927 Weekly Letter Reports.*
[30] Southern California Edison, *1927 Weekly Letter Reports.*
[31] Southern California Edison, *1927 Weekly Letter Reports.*
[32] Southern California Edison, *1927 Weekly Letter Reports.*

Assembly of hydraulic and electric equipment
Plant equipment began arriving at the end of 1927. In the week of December 31, 1927 the bearing blocks for the Pelton unit (Unit 2) arrived, while the rotor casting and end plates were reported to be on their way. The assembly of the Unit 2 rotor took place in January and February under the supervision of a Mr. Redd of the Westinghouse Company (Jan 7, 14). February was occupied with installation of the nozzles and needle assemblies, and waterproofing and other preparations for the wheel pits. In March the construction crews placed Unit 2 rotor on its shaft and began heating it so that it would shrink to fit on the shaft, and assembled the rotor for Unit 1. In April assembly of the water wheels began, and the generator stators were put into place.

On August 5th, the #5 penstock was first filled, and Unit 1 was brought up to speed for the first time on August 6th. The installation of the #2 (Pelton) Unit was completed on December 21, 1928. The interior and exterior of the plant was painted between September and through December 1928, completing construction.[33]

HISTORICAL CONTEXT

California and Electrical Development of the West
California holds an important place in the history of hydroelectric power generation. Despite relatively low rainfall, especially in the southern regions, the high heads available in the state's mountainous terrain made waterpower important in California's industrial development. The mining industry pioneered the development of dam, flume, and penstock technologies at an early date, while Lester Pelton's development of the Pelton wheel in the 1880s dramatically increased the efficiency of the waterwheel in high head settings.[34] In California, however, this energy was typically located in remote areas far distant from urban centers, restricting its use to industries located nearby.

The development of Thomas Edison's integrated system of dynamos, lamps, and circuitry after 1880 led to a boom in urban electrification. However, widespread dependence on direct current, which had a high rate of transmission loss, made the usefulness of electricity dependent on proximity to a central station. The introduction of alternating current transmission and voltage transformers by George Westinghouse after 1886, however, opened up the possibility of transmitting electricity over long distances.[35] Much of the world's pioneering work in AC transmission took place in California, with early world records for distance and voltage set by transmission lines in Bodie (Standard Consolidated Mining Company, 1891), San Antonio to Pomona (San Antonio Light and Power, 1892), and Folsom to Sacramento (Horatio Livermore, 1893).[36]

Once the potential for connecting hydraulic and electrical power was demonstrated by Westinghouse's development at Niagara Falls (1895), hydroelectric development began in

[33] Southern California Edison, *1928 Weekly Letter Reports.*
[34] Hay, *Hydroelectric Development*, 6.
[35] Hay, *Hydroelectric Development*, 9.
[36] Hay, *Hydroelectric Development*, 19, 28.

earnest, and nowhere more intensely than in California. Record-setting developments included the first 33 kilovolt (kV) transmission by Southern California Edison's Santa Ana No. 1 plant (1898); use of a 1,300' head in the Mount Whitney Power Company's plant (1899); and, superlatively, the 140-mile, 60kV Colgate transmission line built by Bay Counties Power Company in 1901.[37] "California," claimed the journal *Electrical West* in 1912, "is the birthplace of real long-distance power transmission on this continent."[38]

Southern California Edison's Big Creek project, begun in 1911, was the apex of early twentieth century hydroelectric development in California and was among the world's largest hydroelectric systems at the time of its construction. The system set successive world records for highest voltage ever used in commercial transmission: 150kV (1913) and 220 kV (1923). Powerhouse 1 and Powerhouse 2A had among the highest heads used in North America – 2,131' and 2,418' respectively. In 1929, at the end of the great expansion of the Big Creek system, the five Big Creek powerhouses (1, 2, 2A, 3, and 8) each held a place among the top ten California hydroelectric plants for kilowatts and horsepower generated.[39]

Origins of the Big Creek System

The Big Creek system was the brainchild of visionary engineer John Eastwood (1857-1924), who first identified the Big Creek and San Joaquin River systems as an ideal location for a series of storage reservoirs and power plants. Eastwood was born in Minnesota and came to California in 1878 to work on the Pacific extension of the Minneapolis and St. Louis railroad. After establishing a private engineering firm in Fresno in 1883, Eastwood turned his attention to the Sierras. In 1893 he first visited the present location of Big Creek town, and saw its potential as the anchor point of a huge hydroelectric generating system. However, demand, distribution, and transmission networks for such quantities of power did not yet exist in California.[40]

By 1895, Eastwood had shown that high-head hydroelectric plants were feasible in the area by developing a plant further down the San Joaquin River for the San Joaquin Electrical Company (today the site of Pacific Gas & Electric Company's Wishon powerhouse). The San Joaquin Electrical Company soon went bankrupt, however, and in 1900 Eastwood turned in earnest to planning and surveying the Big Creek system, securing water rights and identifying locations for tunnels, dams, and power plants.[41] These plans, however, only came to fruition when Eastwood's engineering vision was combined with Southern California capital, in the person of Henry Huntington.

[37] Hay, *Hydroelectric Development*, 30; Hughes, *Networks of Power*, 277.
[38] Quoted in Hughes, *Networks of Power*, 265.
[39] P.M. Downing, O.B. Caldwell, E.R. Davis, W.G.B. Euler, and C.C. MacCalla, "Report of the Sub-committee on Water Development on the Pacific Coast," in National Electric Light Association, *Papers Reports and Discussions, Hydro-Electric and Transmission Sections Technical Sessions, National Electric Light Association Thirty-Eight Convention*, San Francisco: National Electric Light Association, 1915, 594-601; Federal Power Commission, *Directory of Electric Generating Plants* (Washington, D.C.: Federal Power Commission, 1941), 41-54; U.S. Department of Energy, *Inventory of Power Plants in the United States, 1981 Annual* (Washington, D.C.: U.S. Department of Energy, 1982), 41-54.
[40] Shoup, *Hardest Working Water*, 55-59; Whitney, "John Eastwood," 38, 41.
[41] Shoup, *Hardest Working Water*, 60-62; Redinger, *Story of Big Creek*, 6.

Huntington was born in 1850 in Oneonta, New York. His uncle Collis P. Huntington was the force behind the consolidation of the Southern Pacific Railroad. After the death of his uncle, and determined to make his own mark on the industry, Henry Huntington sold his Southern Pacific stock in 1901 and moved to Los Angeles. He became a major figure in the development of the Los Angeles region through his consolidation of street railroads, public utilities, and large real estate holdings. By acquiring land and then connecting it to the metropolis by electric railroad, Huntington was able to sell suburban parcels at hefty profits.[42]

Huntington's expanding network of street railroads depended on a reliable and inexpensive source of electrical power. In 1902, he joined with Allan C. Balch and William G. Kerckhoff to found Pacific Light and Power Company for this purpose. Kerckhoff was born in 1856 and moved to Los Angeles with his family in 1878. Through his father's lumber company he acquired an interest in the San Gabriel Valley Rapid Transit Railway, which was later absorbed by the Southern Pacific. Balch, born in New York in 1864, was trained as an electrical engineer and managed a steam-electric plant in Portland before moving to Los Angeles in 1896. Together, Balch and Kerckhoff founded the San Gabriel Electric Company, which brought them into contact with Henry Huntington.[43]

Huntington was looking for sources of electrical power, while Balch and Kerckhoff had successfully developed a hydroelectric plant on the San Gabriel River, and were proceeding with plans for another on the Kern River, 100 miles to the north. In 1901 and 1902 the three men founded Pacific Light and Power Company with the short-term aim of supplying cheap power to the street railroads, with the eventual aim of consolidating the electric utilities of the greater Los Angeles area into a monopoly.[44] Initially, 51 percent of the company was owned by the Los Angeles Railroad, in which Henry Huntington held a 55 percent interest, with the remainder owned by the Southern Pacific. Balch and Kerckhoff owned 40 percent of Pacific Light and Power, and appointed three of the seven directors, while Huntington named the rest. The intimate relationship between power and railroads at this early date is evidenced by the fact that the power company was formed as a subsidiary of the railroad, and not the other way around.

Kerckhoff and Balch acquired Fresno's San Joaquin Electric Light and Power in late 1902 as a large source of low cost power that could meet the projected demands of the fast-growing metropolis of Los Angeles.[45] At the time, John Eastwood was Vice President and Chief Engineer of San Joaquin Electric Light and Power. Balch and Kerckhoff were receptive to Eastwood's plans for Big Creek, and hired him in July 1902 to fully plan the system. Eastwood immediately began filing water rights claims and by late 1903 had claimed over 410,000 miner's inches of water in the basin.[46] By 1905, Eastwood had prepared plans for a system of powerhouses and transmission lines that by his estimate would offer considerable savings over similarly sized

[42] Shoup, *Hardest Working Water*, 66.
[43] Shoup, *Hardest Working Water*, 67-69.
[44] Shoup, *Hardest Working Water*, 74.
[45] Shoup, *Hardest Working Water*, 71.
[46] Shoup, *Hardest Working Water*, 75.

steam plants.[47] Pacific Light and Power's directors, however, were uncertain whether existing demand could absorb the huge quantities of power that Eastwood's proposed plants would generate, and decided in 1903 to prioritize steam development over hydroelectric. As a result, the period up to 1910 saw little progress on the Big Creek project.

Despite this delay, Eastwood continued to file water claims and began securing permits from the U.S. Department of the Interior to develop the hydroelectric plants, which are located on Federal land on the Sierra National Forest. Road permits were granted in 1903-1904 and comprehensive permits for the initial Big Creek development issued in 1909.[48] In 1906 Pacific Light and Power reached an agreement with Miller and Lux, a land and livestock company holding much of the downstream water rights on the San Joaquin River, and in late 1905 construction of a road from Shaver (then a timber camp) to the Big Creek basin was begun. Another route, from Auberry to Camp 1 (the site of today's Big Creek town), was begun in 1908.[49]

By 1905, Eastwood had outlined his vision for the initial development of the Big Creek system. He identified the later locations of Powerhouses 1 and 2 as the sites for two powerhouses with 2050 and 1861 feet of head, respectively. In his proposal, each plant would have six 7,500 horsepower (hp) water wheels generating over 40,000hp of electricity. His projected power lines were to transmit either at 66kV or 88kV. His design for the powerhouses proposed a separation between the generators, transformers, and transmission equipment:

> The portion to be blasted out will not be great, as the buildings will be narrow, and the outer walls will be carried up, and the floors leveled with broken rock, the buildings rising one above another in steps, the generator house first, the transformer house next, and the line house and tower at the top…
>
> The generator house will be located nearly on a level with the bed rock at the creek, and parallel with the creek channel, the inner edge being blasted out of the bluff, and the outer edge being built up to bring the floor up to a level.
>
> This building will need to be 210 feet long, inside and 40 feet wide, with an alcove to accommodate the exciters and the switching gallery… The transformer house will be separated from the generator room by a fire wall the entire hight *[sic]* of the building, and separate stalls provided for the transformers, and will lighted *[sic]* from a skylight and from windows arranged above the traveling crane, and at the ends of the building, and will be 210 x 30 feet inside.
>
> The line house and tower, will contain the lightning arresters, and the main transmission line terminals, and will be built with a dead wall in front, and lighted from the upper side,

[47] John S. Eastwood, "Comparative Estimate of Cost of Water-Power Transmission Plant vs. Steam Plant, for W.G. Kerckhoff, President, Pacific Light and Power Company," 1905, Document No. 12871, in History and Information File, Northern Hydro Division Headquarters Library, Big Creek, California.
[48] Shoup, *Hardest Working Water*, 82.
[49] Shoup, *Hardest Working Water*, 83.

> and will be 60 feet long and 30 feet wide inside, surmounted by a tower 24 feet square inside, provided with open ports for the exit of the lines.
>
> There is no reason why, with the almost ideal conditions to be met at this site, it should not be a model plant, not only from the point of permanency, economy and certainly of output, but in the way of tasteful and convenient design and architecture as well, in as full a degree as consistant *[sic]* with its location and uses.[50]

Although the eventual design of Powerhouses 1 and 2 departed considerably from Eastwood's original vision, many of the principles laid out in this initial design remained the same: the creek side location, the length of the building, the use of fire walls to separate equipment, and the separation of transformers in stalls. Eastwood was in fact ahead of his time in proposing the physical separation of different functional elements of the plant, an approach to powerhouse construction that become standard after the early 1920s.

He also identified locations for Powerhouse 3 and a larger Shaver Dam (then owned by the Fresno Flume and Lumber Company), and anticipated the use of water from Mono Creek and Mammoth Lakes. As we will see below, all of these facilities were eventually constructed in the locations proposed by Eastwood – although the power eventually supplied by the system was considerably more than even he anticipated.[51]

By 1909-1910, Huntington, Kerckhoff, and Balch began seriously considering the fulfillment of Eastwood's hydroelectric plans. A consultant estimated the cost of the two initial power plants at $12.34 million. To ensure the soundness of the investment, Huntington hired the Chief Engineer of the Southern Pacific Railroad to estimate the potential revenues from the project. The assessment concluded that the Big Creek system would lose money. Rather than canceling the project, however, Balch and Kerckhoff ordered construction of a weir to more precisely calculate water flows on Big Creek.[52]

Meanwhile, Huntington was taking steps to raise capital for the project. Pacific Light and Power Company was recapitalized in late 1909 with the help of eastern bankers and sold new bonds to raise money for the Big Creek project. At the same time, Huntington eliminated the Southern Pacific Company from the project by trading one of his interurban electric lines in Los Angeles for the Southern Pacific's 45 percent stake in the Los Angeles Railroad, Pacific Light and Power's holding company. In 1910, Balch exercised his option to buy the plans, water rights, and permits for Big Creek, all of which were held in Eastwood's name. Eastwood received 10 percent of the stock of the new Pacific Light and Power Corporation.[53] Huntington, however, used special assessments on shareholders to force Eastwood to sell his stock cheaply, depriving him of his hoped-for wealth. Despite his visionary role in designing the Big Creek project,

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[50] John S. Eastwood, "Progress Report for 1903-1904 of Right of Way Surveys and Outline Plan for Power Plant No. 1," 1904, 38-39, in Folder 11, Box 302, Southern California Edison Papers, Huntington Library, San Marino, California.
[51] Eastwood, "Comparative Estimate."
[52] Shoup, *Hardest Working Water*, 85-86.
[53] Shoup, *Hardest Working Water*, 85.

Eastwood was excluded from involvement in its construction and ultimately received no financial reward for his work. Balch and Kerckhoff also sold their interests to Huntington about this time, leaving him with full control of the company. About the same time, in October-November 1911, Huntington secured financial backing from a syndicate of New York bankers that allowed construction to proceed.[54]

Initial Construction, 1910-1913

Once the financial resources to construct the project had been secured, construction was ready to begin. Pacific Light and Power, however, lacked the large workforce or engineering expertise to quickly begin construction. Instead, it hired the Boston-based Stone and Webster Construction Company to design and manage the construction. The contract with Stone and Webster covered the construction of the 56-mile San Joaquin and Eastern Railroad, three dams to create Huntington Lake, Powerhouses 1 and 2, the 240-mile transmission line to Los Angeles, and the necessary forebays, tunnels, and penstocks.[55] Authorization to begin construction of the railroad was given on January 26, 1912.

Work on the railroad proceeded in a climate of secrecy, since all of the necessary rights-of-way had not yet been secured. Construction of the railroad raised difficult engineering problems. Most famously, one section of the route passed across a bedrock face on tracks bolted directly to the stone. The railroad was completed on July 12, 1912 – only 165 days after work began.[56]

The development as executed by Stone and Webster followed Eastwood's plans in the main, although Stone and Webster's engineers favored different architectural and engineering solutions: their engineers built Cyclopean masonry dams with gravity sections rather than his proposed earth dams, and combined the generation and transmission facilities in a single structure rather than separating them in detached buildings as Eastwood had proposed.[57]

In March 1912, blasting for the dam sites and tunnels began. Over the summer of 1912, 3,500 men were at work in 12 camps scattered across the construction area. Dam and tunnel construction continued until the end of 1912. Huntington, Balch, and Pacific Light and Power's Vice President George C. Ward visited the site of construction in July 1912, in what was to be Huntington's only visit to Big Creek. Preparations for constructing Powerhouses 1 and 2 commenced in late 1912, when Stone and Webster established a sawmill to cut timber logged out of the area. The lumber would be used for construction forms for the powerhouses. At the end of 1912 excavation for the foundations of Powerhouse 1 were well underway.[58] At the same time, the process of securing final permits from the Department of Agriculture (the parent agency of the U.S. Forest Service) continued. Ward filed the application for a final Power Permit on July 16, 1912 with amendments in November. The Department of Agriculture was apparently slow to respond, for Southern California Edison archives contains a letter of March 1913 noting that

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[54] Shoup, *Hardest Working Water*, 85, 92.
[55] Redinger, *Story of Big Creek*, 11; W. Sohier, *The Big Creek Project, A History, December 27, 1917*, typescript, 9-10, in Folder 7, Box 302, Southern California Edison Papers, Huntington Library, San Marino, California.
[56] Shoup, *Hardest Working Water*, 95.
[57] Eastwood, "Progress Report."
[58] Stone and Webster, "Progress," 3.

issuance of the permit was an urgent matter, since construction work was well underway. It was not until July 16, 1913 that the Department of Agriculture finally issued the final power permit for Big Creek Powerhouses 1 and 2.[59]

The pivotal construction year of 1913 opened with bad weather and a general strike. Working conditions were difficult: workers complained of long days and bad food, while typhoid and other diseases struck the camps. Accidents killed or maimed several workers, sparking a visit from the state labor commissioner in late 1912.[60] When several men were fired for trying to attack one of the cooks, over 2,000 men went out on a strike led by members of the Industrial Workers of the World, a radical anarcho-syndicalist union. Demands included time-and-a-half pay for overtime, hot water in the washrooms, better sleeping quarters, access to doctors, and better food. The strike began at Camp No. 3 on January 7 and spread quickly to the others. In response, Stone and Webster closed the mess halls, locked out its employees, and suspended work at Big Creek. Almost 2,000 men were fired outright, and striking workers had no choice but to leave the area.

The record snowfall that week provided a convenient excuse for suspending the project while Stone and Webster hired a new workforce. By January 25, construction on the powerhouses had resumed.[61] Between the strike and the bad weather, however, the Big Creek project had fallen behind schedule. Originally set for completion on July 1 and October 1, 1913, Powerhouses 1 and 2 were not completed until November and December. This delay reduced the projected revenues from the plants, requiring Pacific Light and Power to raise additional funds to complete construction and causing the temporary layoff of some of the construction workforce.[62]

In March 1913, excavation had been completed and the foundation of Powerhouse 1 was poured.[63] The powerhouse structure was built in just three months, with the roof finished in July 1913. The generators first went on line on October 14, 1913, though the plant did not begin transmitting power to the Eagle Rock substation in Los Angeles until November 8. Due to the fire of October 17, 1913, Powerhouse 2 was further delayed: Unit 3 did not go online until December 8, 1913, and Unit 4 began transmitting on January 11, 1914.[64]

The structure of Powerhouse 2 was almost complete in mid-October of 1913. However, on October 17, 1913, a fire swept through the upper floors of the nearly complete powerhouse, destroying part of the roof, the internal partitions on the upper floors, and some of the equipment. This fire seems to have been begun accidentally in the small saw mill attached to the construction site, though Southern California Edison's 1922 Valuation of Powerhouse 2 suggests that it was of an 'incendiary nature,' hinting that it may have been a case of arson.[65] Powerhouse

[59] Sohier, "The Big Creek Project," 26. More information on Big Creek permits up to 1957 is held in Folder 6, Box 302, Southern California Edison Collection, Huntington Library, San Marino, California.
[60] Shoup, *Hardest Working Water*, 127.
[61] Shoup, *Hardest Working Water*, 132.
[62] Stone and Webster, "Progress," 3; Kelley, *Valuation*, 8.
[63] Kelley, *Valuation*, 30.
[64] Redinger, *Story of Big Creek*, 31-32.
[65] "Fire at Big Creek Causes Damage of $10,000," *Fresno Morning Republican*, October 20, 1913.

2 Unit 1 did not go online until December 8, 1913, and Unit 2 began transmitting on January 11, 1914.[66]

When the initial phase of Big Creek was complete, the two powerhouses had four generating units producing 80,000 horsepower and using some of the highest heads in the country. At 240 miles long, the power lines connecting Big Creek with Los Angeles were among the world's longest, and set a new record for using 150kV in commercial transmission. The vision of Big Creek as an integrated system of plants which could be added to was also ahead of its time and anticipated the interconnected systems that characterize power production and transmission today.

Other large plants built about this time, such as Keokuk (Illinois) and Conowingo (Maryland), generated more power, but none were built under conditions as difficult as those at Big Creek. The difficult mountain terrain, high heads, and huge turbines gave the Big Creek plant an essentially experimental character. *Electrical World* recognized the feats achieved in the initial construction of the system as "one of the most advanced contributions of the engineer to the welfare of civilization."[67]

Intermission, 1914-1919
While Big Creek Powerhouses 1 and 2 were designed for later expansion, the onset of the European war in late 1914 affected both the American credit markets and power consumption. It became difficult for companies such as Pacific Light and Power to raise money for capital projects, while electrical demand in Los Angeles was not growing fast enough to require immediate construction of additional power plants or generating units.[68]

Despite this relative lull, some construction did continue at Big Creek. Crews began work on Tunnel 3, which was to connect Powerhouse 2 to the proposed Big Creek No. 3 development. However, only 2050' of tunnel were bored between July 1914 and February 1920. In summer 1917, the three dams at Huntington Lake were raised to an elevation of 6950', increasing the lake's storage capacity and allowing the later installation of a third generating unit in Powerhouse 2.[69]

More significant for the future development of the Big Creek system was the 1917 merger between Pacific Light and Power and Southern California Edison (SCE). Henry Huntington had dreamed since at least 1902 of consolidating southern California utilities under his control. The merger, which was accomplished through a swap of PLP and SCE stock, made sense from a business point of view. PLP had extensive street railroad interests but limited residential service, and the Big Creek plants provided more electricity than it could use. Edison, on the other hand, had a rapidly expanding residential business and was facing a looming shortfall of generation

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[66] Redinger, *Story of Big Creek*, 31-32.
[67] "The 150,000-Volt Big Creek Development-I," *Electrical World*, January 3, 1914, 33.
[68] Shoup, *Hardest Working Water*, 153.
[69] David H. Redinger, "Progress on the Big Creek Hydro-Electric Project, Part I," *Compressed Air Magazine*, December 1923, 722.

capacity. The two systems complemented each other, as the California Railroad Commission observed when it approved of the merger in 1917. As *Electrical World* noted at the time,

> this merger of what are really vast interests is undoubtedly along the lines of wise business policy. The two electric companies have been operating side by side in a rapidly growing territory, competing keenly for business in a number of centers, and to some extent duplicating investment and wasting energy which could be better utilized in other directions.[70]

The newly merged company had two vice presidents from the Pacific Light and Power side, R.H. Ballard (formerly corporate secretary) and George C. Ward (formerly vice president), while Henry Huntington, his son Howard, and his lawyer W.E. Dunn each took seats on the Board of Directors.

After the end of the First World War in late 1918, an economic boom began. Capital was again available, and rapid urban and industrial growth in Los Angeles had radically increased demand for electricity. A new source of energy was needed quickly. As a result, the previously modest expansion plans for Big Creek were accelerated.[71] In October 1920 Southern California Edison applied to the California Railroad Commission for approval of their proposal to expand Powerhouse 1 and construct two new powerhouses, to be called Powerhouse 3 and Powerhouse 8. Permission was granted in Railroad Commission decision 8569 on January 20, 1921.[72]

The original plans for Powerhouse 3 had called for it to utilize a head similar to Powerhouses 1 and 2 (1500'). The development of more efficient vertical turbines in the intervening years, however, made it possible to extract more power from a lower head. As a result Edison decided to divide the head originally intended for Powerhouse 3 into two power plants. Powerhouse 8 (so numbered because numbers up to 7 had already been used in Federal permit applications) was to be built first at the junction of Big Creek and the San Joaquin River. The construction of Powerhouse 8 in early 1921 set off a period of continuous expansion of the Big Creek system that lasted, almost without interruption, until 1929.

The Big Creek Community on the Eve of the Great Expansion

The 1920 United States Census was conducted just as the great expansion of the Big Creek system was getting underway. While the population of the region would eventually swell to over 5,000 at the height of construction work, only 535 people lived in the "Cascada Precinct" of Fresno County when the census was conducted in 1920. The precinct included the town of Cascada (renamed Big Creek in 1926) and the nearby construction camps. The census data provides us a snapshot of the community and its demographics that provides some insight into the social world of Big Creek in the early period of its operation.[73]

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[70] "Merger of California Hydroelectric Systems," *Electrical World*, December 9, 1916, 1134.
[71] Shoup, *Hardest Working Water*, 162.
[72] Noted in an untitled memorandum in Folder 6, Box 302, Southern California Edison Collection, Huntington Library, San Marino, California.
[73] Fourteenth Census of the United States, Cascada Precinct, Fresno County, California.

The Big Creek community in 1920 was overwhelmingly male, with 426 adult men but only fifty-eight women and fifty children. There were only fifty-two married couples in the community, although ninety-four men were listed as married. While some of the married couples took on individual boarders, most of the men lived in boarding houses or bunkhouses with from ten to fifty-six occupants. This dense occupancy is reflected in the fact that the area contained only seventy-nine dwellings for 535 people.

Twenty-three of the married couples had children. Of the fifty-eight women residing in the Cascada precinct, fifty-two were married, three widowed, and three single. Two of the single women, aged 19 and 21, were the eldest daughters of a foreman. The other, aged 21, was the grammar school teacher. Two of the widowed women, aged 61 and 60, lived in Big Creek with their working sons. A 35 year-old widow, living with her 7-year-old son, was the proprietor of one of the boarding houses.

The vast majority of employment in the Cascada Precinct was through Southern California Edison: of the 432 adults with jobs, 365 worked for the "power company" or within a "power company camp." Another thirty-five men worked for the San Joaquin and Eastern Railroad, also owned by Southern California Edison. Twenty men worked in construction, at a warehouse, or in a sawmill – possibly the employees of the Fresno Lumber and Irrigation Company in the town of Shaver, now Shaver Lake. The remaining residents, twelve in number, were shopkeepers, hotel operators, or providers of other basic services. Cascada, in other words, was a company town fully dependent on the Big Creek powerhouses.

Over half (189) of the Edison employees were recorded in the 1920 census as "laborers." Others had more skilled employment as carpenters (35), mechanics or machinists (18), engineers (18), electricians (10), teamsters (13), and clerks. Other jobs included blacksmiths, timekeepers, painters, miners, riggers, pipefitters, and cement workers. Supporting the community were fourteen cooks, twelve waiters, five storekeepers, four boarding house workers, two nurses, a doctor, and a grammar school teacher. The average age of Edison employees at the time of the census was 37.

Most residents of the Big Creek area in 1920 were native-born Americans, and all listed their race as "white." Only around one third were foreign born, and most of these had come from northwest Europe. More than twenty nations of origin were represented in the community. The largest group was Irish (21), followed by English (16), Swedish (14), Canadian (13), German (12), Scottish (8), Italian (8), and Russian (7). All of the foreign-born came from either Europe or Canada, except one from Siberia, one from Chile, and one from South Africa. Over two-thirds of the foreign-born workers, however, had been in the U.S. more than ten years.

Powerhouse 8: The "Ninety Day Wonder"

This community would soon be swelled by the addition of thousands of new construction workers. The great expansion of the Big Creek system began in early 1921, when the construction of Powerhouse 8 began. Excavation for the foundation of Powerhouse 8 took place between January and early May, with the first concrete was poured for its foundation on May 12. The turbine parts were assembled as concrete was being poured for the powerhouse structure, and installation of Unit 1 commenced in June. On August 11, Powerhouse 8 began generating power, and was connected to the system on August 16.[74]

Powerhouse 8 was a pioneer facility in several respects: it was the first commercial powerhouse ever designed for 220kV transmission, it was among the first to use the improved Francis-type vertical reaction turbine, and its generation capacity from the single initial turbine almost matched that of both units in Powerhouse 1 (27,000kW compared to 28,000kW). Powerhouse 8 also set records for the speed of construction, which continued 24 hours per day, 7 days per week and earned the plant the moniker of the 'Ninety-day wonder.'[75]

Powerhouse 3: "The Electrical Giant of the West"

In September 1921, soon after the completion of Powerhouse 8, construction began on the tunnels, forebays, and penstocks for Powerhouse 3.[76] The revised plan for this station was similar to that of Powerhouse 8: it would also use Francis-type vertical reaction turbines operating under a relatively low head (827'). The engineering challenges of Powerhouse 3 were considerable, requiring 30,000' of tunnel work, the blasting of a 6 mile road into a sheer granite face, and extensive foundation excavation. This work continued throughout 1922.

On November 15, 1922 the excavation for the Powerhouse 3 forebay was complete and the erection of concrete forms was begun.[77] The dam was completed in February 1923. Excavation for the foundation of the powerhouse started June 5, 1922 and was completed January 10, 1923. The three initial units of Powerhouse 3, "the electrical giant of the West," were placed online on September 30, October 2, and October 5, 1923.[78] Though Big Creek 3 was planned for eventual expansion to six units, the structure as built in 1923 had room for only four, while only three were installed at first. Even with only three units, however, Big Creek Number 3 was the largest hydroelectric plant in the west, with an aggregate capacity of 75,000kW. The powerhouse also incorporated several innovations in design, such as an outside switchyard and a two-level generating floor that eliminated the need for a basement.[79]

Additional Units and 220kV Transmission

Each of the Big Creek powerhouses was designed for later expansion. Work on a third generating unit at Big Creek No. 2 was authorized in late 1918 and began in summer 1920. Structural work was completed that November, and the new unit was paralleled to the system on February 1, 1921. The Shaver Tunnel was also begun in February 1920 and completed in May 1921. This tunnel diverted water from Shaver Lake into the Big Creek drainage, allowing its use in Powerhouse 2 and the plants below. Initially this water was simply diverted into the

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[74] "Big Creek No. 8 Hydro-Electric Unit Completed," *Journal of Electricity and Western Industry*, August 15, 1921, 160.
[75] Shoup, *Hardest Working Water*, 190; "First 220,000-Volt Station Completed," *Electrical World*, 117.
[76] "Southern California Edison Company to Start 150,000-Kw. Station," *Electrical World*, September 24, 1921, 636.
[77] Redinger, "Progress I," 838.
[78] David H. Redinger, "Progress on the Big Creek Hydro-Electric Project, Part V," *Compressed Air Magazine*, September 1924, 991.
[79] "Work Progressing Rapidly on Big Creek No. Three," *Journal of Electricity and Western Industry*, May 1, 1923, 341.

Powerhouse 2 forebay, though it was later used in Powerhouses 2A, 3, and 8 upon their completion.

Work to convert Big Creek's 150kV transmission system to 220kV was completed on May 6, 1923, when the Big Creek system began transmitting at the highest voltage used commercially anywhere in the world.[80] In July 1923 Powerhouse 1 was expanded to add a third unit, which was brought on line on July 12. In late 1924 and 1925 Powerhouses 1 and 2 were expanded to their full planned capacity by the addition of a fourth unit to each. This addition required extension of the powerhouse structures by 56' each.[81]

Florence Lake, the Mono-Bear Conduit and Shaver Dam

The later 1920s saw efforts to increase the available water in the Big Creek system by increasing storage capacity and drawing from adjacent watersheds. Between 1925 and 1928, tunnels and dams were built from Mono Creek, Bear Creek, and the south fork of the San Joaquin, while the dam at Shaver Lake was raised to increase its storage capacity.

The years 1925 and 1926 saw the construction of the dams that created Florence Lake on the south fork of the San Joaquin River. Work on the Florence Lake Tunnel (later named the Ward Tunnel for Edison President George C. Ward), which connected the south fork watershed to the Big Creek system, had begun in 1920 and was finished in April 1925. For the dam, a multiple-arch design was chosen, a type pioneered by John S. Eastwood. Construction began in March and was completed in November 1925, although the dam was raised again in 1926.[82] The Mono-Bear diversion drew water from Bear and Mono Creeks, located downstream from Florence Lake, into the Ward Tunnel and thence into Huntington Lake. Constructed between 1925 and 1927, these tunnels required excavation through solid granite.[83]

Shaver Lake, originally built by the Fresno Flume and Lumber Company as part of their logging and sawmill operation, was raised between 1925 and 1927, expanding the lake to 2,200 acres in surface area. The new Shaver Lake was designed to store excess water from Florence and Huntington Lakes and also to make possible new high-head generating units that would be known as Powerhouse 2A.[84]

Powerhouse 2A and the End of the Great Expansion

The availability of water from Florence Lake and Shaver Lake led to the ambitious expansion of Powerhouse 2. Two additional units were constructed in a new building adjacent and connected to the older building. Powerhouse 2A would harness a 2,418' head, the highest in the Big Creek system and one of the highest in the United States. Construction of Powerhouse 2A began in June 1926 and cost $23 million.[85] Units 1 and 2 went online on August 21 and December 21,

[80] "Transmission at 220,000 Volts a Fact," *Electrical World*, May 12, 1923, 1107.
[81] "Big Creek No. 2 Powerhouse Being Extended," 297; Southern California Edison, "Memorandum," 1-2.
[82] Redinger, *Story of Big Creek*, 136, 150.
[83] Redinger, *Story of Big Creek*, 149.
[84] Redinger, *Story of Big Creek*, 153.
[85] "Southern California's Advance," *Electrical West*, April 21, 1928, 829.

1928, respectively.[86] The 56,000 hp turbines and 46,500kW generators were among the largest in the world at the time of their installation. Although Powerhouse 2A drew water from Shaver Lake and had its own transmission line, the new building was operated from the Powerhouse 2 control room.[87]

When the second unit of Powerhouse 8 went on line in June 1929, the great expansion of the Big Creek system was concluded.[88] Fifteen generating units were in service, with a aggregate capacity of 344,800kW. The system went from generating 213 million kilowatt-hours in 1914 (its first full year of service) to 1.6 billion kilowatts in 1928.[89] From the opening of Powerhouse 1 in 1913 to the end of 1929, the Big Creek system had set a series of records for generation and transmission that earned it a preeminent place among the electrical generating systems of the west and of North America.

Powerhouse	**Unit**	**Capacity (kW)**	**Installation date**
1	1 2 3 4	14,000 14,000 14,000 22,400	1913 1913 1923 1925
2	3 4 5 6	14,000 14,000 14,000 14,000	1913 1913 1921 1924
8	1 2	22,400 34,000	1921 1929
3	1 2 3	25,000 25,000 25,000	1923 1923 1923
2A	1 2	46,500 46,500	1928 1928
Total	**15**	**344,800**	

Table 1. Big Creek Generating Capacity at the end of the Great Expansion.

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[86] Southern California Edison, "Memorandum," 3.
[87] Redinger, *Story of Big Creek*, 157; "Southern California Edison's Advance," 829.
[88] "Second Unit Installed at Big Creek Plant No. 8," *Electrical West*, July 1, 1929, 38.
[89] Southern California Edison, *1928 Annual Report, Big Creek Division*, 21, in History and Information File, Northern Hydro Division Headquarters, Big Creek, California.

Operating the Powerhouses

The degree to which the Big Creek Powerhouses, especially Powerhouses 1 and 2, were experimental technologies can be seen in the daily operators' logs, which remain on file at the plants. The logs reveal how operators dealt with frequent minor mechanical problems, and a few major ones such as penstock breaks. The experience led to innovations in safety procedures, and a focus on accident avoidance that remains a characteristic of Southern California Edison corporate practice today.

JOB CLASSIFICATIONS

Big Creek Nos. 1 and 2 began operation in late 1913 with three to five men on duty. Shifts were initially ten hours, but were reduced to eight hours by 1920. The plants maintained a three-shift schedule: 8am-4pm, 4pm-midnight, and midnight-8am. These rotations were also observed in Big Creek Nos. 3 and 8 when they came on line in 1921 and 1923 respectively. In 1929 the Big Creek division employed forty-nine powerhouse operators in the four plants, at the grades of "shift operator," "operator," "assistant operator," and "probationer." Besides the operators, each powerhouse had a station chief, assistant chief, electrician, machinist, two utility men, and a cook for the boarding houses.[90]

A shift schedule prepared by Big Creek 8 station chief P.H. Hilbert in early 1926 provides an example of how these classifications were divided into shifts:

	{Shift Operator
A.M Shift	{Switchboard Operator
	{Relief Asst. Operator
	{Asst. Station Chief
Day Shift	{Switchboard Operator
	{Machinist or Electrician
	{Shift Operator
P.M. Shift	{Switchboard Operator
	{Relief Operator or Electrician

Hilbert notes that in this arrangement, the station machinist and station electrician would be each available for maintenance work for twelve days each month.[91] Plant daily logs show that other plants also maintained a workforce of three or four men per shift during the 1920s.

[90] Southern California Edison, *1929 Annual Report, Big Creek Division*, 4, in History and Information File, Northern Hydro Division Headquarters, Big Creek, California; see Southern California Edison, *1927 Annual Report, Big Creek Division*, 29, in History and Information File, Northern Hydro Division Headquarters, Big Creek, California, for operator grades.

[91] P.H. Hilbert to R.B. Lawton, "Big Creek No. 8 Operating Shift Schedule," memorandum dated February 19, 1926, in File 29-940.1, Archive Room, Big Creek Powerhouse 8.

OPERATOR TASKS

The main task of the powerhouse operators was to adjust power production to fluctuations in load on the overall Edison system, which were dependent on demand in the greater Los Angeles area. Most of the operators' daily tasks, however, were more mundane. They included testing equipment, performing routine maintenance, and cleaning the station. The daily log for December 18, 1926 from Big Creek 3 gives the flavor of the work:

> 12 midnight. Hess, Batzer, Morgan – on. Thompson – off.
> Station normal. Greased #3 Turbine and swept kitchenette, washroom, and office. Cleaned door, sinks, urinals, bowls, and tubs in main washroom. Emptied trash barrel from machine shop. Burnt all garbage and swept hallway. Cleaned up a few grease stains on gen. floor.
>
> 8am. Lockyer, Leahy, Horr – on. Morgan – off.
> Station normal. Repaired opening bolt #15 unit #3 turbine. Took voltage of batt. Swept part of gen. floor. Ran purifier #1 turbine, about 20 gal's water. Wiped #2 turbine.
> Station duties – Horr.
>
> 4pm. Lee, Strain, Thompson – on. Horr – off.
> Station O.K. Wound Venturi Meters. Wiped #1 Turbine and room. Took specific gravity of station batteries and of three cells of A and B Carrier Current Telephone Batteries. Cleaned windows along North wall on generator floor. Cleaned and mopped Kitchenette. Greased #1 H. [house] Set, and water pumps. Changed pumps and compressors.
> Station duties – Thompson.[92]

The handwritten logs, which are extant for all four powerhouses, offer meticulous detail about the working lives of their operators during the period of significance.

THE EVOLUTION OF SAFETY PRACTICE

The Big Creek plants deployed cutting-edge technology for their day. Innovation, however, brought with it both hazards and significant technical challenges. In the early period of operation it was the penstocks in particular which provided many of the mechanical failures in the plant. The first such incident occurred at Powerhouse 1 just after 1 am on December 1, 1913, only a few months after the plant was placed in service. A broken penstock joint sent water and debris cascading down the hill and against the back wall of the plant. A.C. Prigmore, the station chief, reported:

> Tried to notify Mr. Lawton by phone but found telephone line shorted and sent up messenger, by this time water had raised up back of building to the window sills and rear door gave way letting flood in between agitators thru be plates of exciters and down into basement. Notified Eagle Rock we would have to shut down at once… Water level in

[92] Big Creek No. 3, *Floor Log Volume 11 (1926-1927)*, 97, in Archive Room, Big Creek Powerhouse 3.

> generator pits [was] about a foot and a half above bottom each. Entire length of basement passage filled with sand and rubbish to within a foot of the ceiling, most of it comming *[sic]* in from opening at the West end of building. Sand and rocks covered the floor around the agitators to the top of the foundations.[93]

It took two weeks to return the plant to operative condition.

A worse accident occurred on March 14, 1924, at Big Creek No. 3. A machinist named Johnson and his helper Childs were working on a stuck plunger valve inside Penstock Number 3 when water rushed into the pipe. As the investigative committee reported:

> The helper was close to the manhole and succeeded in getting out. Johnson was caught and killed, his body being torn to pieces and forced out through the turbine relief valve. Water was discharged through the manhole and tore a large hole in the roof, spouting a hundred feet or more above the powerhouse. Part of the air duct for #3 generator was torn away and several windows between the generator room and gallery were broken. The power house was flooded, several inches above the main floor.[94]

Johnson's death led to serious introspection in the Big Creek Division. The investigative committee determined that the accident occurred because "responsibility [was] divided between operating and construction organizations and the lack of definite rules as to obtaining clearances to do construction and repair work."[95]

In response, the committee recommended improvements to mechanical safety, including mechanical locks on valves and disconnection of electricity to forebay gates during penstock maintenance. They also recommended that definite rules be established for obtaining maintenance clearances. The procedures suggested by the committee were implemented quickly. Powerhouse daily logs and floor logs from the mid-1920s show that new clearance forms were used when maintenance was required on potentially dangerous machinery such as valve pits, governors. The forms named the employee cleared to do the work, and were countersigned by the station chief and dispatcher. The apparatus itself was checked by two further employees, and the final clearance to begin the work signed by the foreman on duty.[96] By ensuring that everyone on duty knew that the work was being performed, the new procedure responded to the failures in communication that were evident in the 1924 tragedy.

Beyond these specific procedures, an increasing emphasis on safe working conditions evolved in the Edison organization during the 1920s. Weekly letter reports and annual reports prepared by Station Chiefs track the number of injuries and days lost to illness, with evident pride when the numbers remained low. The Big Creek Division Report for 1927, for instance, notes only 296

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[93] Big Creek No. 1, *Daily Log*, December 1, 1913, in Archive Room, Big Creek Powerhouse 1.
[94] W.R. Battey, George C. Heckman, and J.M. Gaylord to Mr. B.F. Pearson, letter regarding the Big Creek Number 3 penstock accident, March 19, 1924, in Archive Room, Big Creek Powerhouse #3, Big Creek, CA.
[95] Battey et al., letter to Mr. B.F. Pearson.
[96] An example of this form can be seen in Big Creek No. 3, *Floor Log Volume 12 (1927)*, 193, in Archive Room, Big Creek Powerhouse 3.

hours off for sickness and 164 off for injury out of 244,078 payroll hours – barely one-fifth of 1 percent.

> A mistake in switching at Big Creek #3 on June 12, 1927, is the only mistake we have to report for the entire Big Creek Division.
>
> Big Creek Plants numbers 1 – 2 and 8 have a clear record for two years. No avoidable accidents to employee in any plant.
>
> A great deal of credit is due to Careful Clubs, Station Chiefs and Employees for the interest they are taking in this branch of the work.
>
> The Big Creek Division Maintenance Crew has a clear record for the last two years. No accidents or mistakes resulting in damage to property or injury to person.[97]

The company established Careful Clubs to provide safety training at each powerhouse, with rewards for stations and individuals for maintaining a clean safety record for periods of six months, one year, and two years. This emphasis on safety practice represents the early phase of the 'safety first' culture that remains a hallmark of Big Creek operations today.

RETENTION AND TRAINING

Given the isolation and harsh winter climate of the Big Creek area, recruiting and retention of skilled employees was an ongoing problem. In an early 1922 letter to Southern California Edison's Superintendant of Generation, the Big Creek superintendant wrote of the difficulties he faced:

> As the annual vacation period is near at hand, and it will be necessary at that time to secure relief for the three Big Creek plants, writer would suggest that an effort be made to secure a better class of men than we have been getting in the past. By a better class of men I mean men that have received at least a high school education, and some technical as well if possible, and who have had some mechanical and electrical experience… We have filled our plants with men who in the majority of cases were simply looking for a job. The result is that out of the entire Big Creek operating organization, only a very small percentage have the inclination or ability to fit themselves for responsible positions. The operation of the plants and system is going to become increasingly difficult and complicated by the addition of more and larger plants and units, automatic and semi-automatic protective equipment and increased transmission voltage and in the writer's opinion is going to require a much higher grade of men to successfully and properly handle this equipment than we have been getting the last few years.[98]

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[97] Southern California Edison, *1927 Annual Report*, 28.

[98] R.B. Lawton to D.D. Morgan, "Operating Force-Big Creek," undated memorandum, probably 1922, in File 29-939, Archive Room, Big Creek Powerhouse 8, Big Creek, California.

Another dimension of the problem was the very high employee turnover experienced at Big Creek, especially in the construction workforce. As the shareholder magazine *Edison Partners* magazine reported in 1923:

> Under the plan of permanent organization of the construction forces the labor turnover on the Big Creek-San Joaquin project has been constantly decreasing, until the average for the past year was forty per cent, and the lowest average for any month twenty-six percent. Good living conditions, excellent food, commissary stores which sell everything from clothing to cigarettes at the same prices that obtain in the large cities, amusements, recreation halls, and greatest of all, that intangible thing which can perhaps be termed "camaraderie" and co-operation tend to contentment among the men, and a desire to consider the project in the nature of a life work.[99]

Despite the rosy prose, the writer concedes an average of forty percent turnover *per month* in the construction workforce, suggesting that many of the workers on the construction jobs at Big Creek during this time found the work too hard, the conditions too isolated, or the pay too low to remain on the job for more than a few months.

This level of turnover may have been specific to the Construction Department.[100] The 1927 Annual Report for the Big Creek Division shows that only 37 of 139 employees left during the year, an annual turnover rate of 26.6 percent (or 2.2 percent per month). Of these, fourteen received transfers within the Edison organization, "in most cases at the request of the company."[101] While this remains a high rate, it suggests that the permanent operating employees at Big Creek had more satisfaction with their work.

To address these problems, Edison implemented programs in the mid-1920s to improve employee education and retention. These often began with basic mathematics. As Big Creek 3 Station Chief O.C. Bangsbury reported in 1927:

> As has been requested, regular classes will be held once a week, starting with Shop Arithmetic. The class has been organized and the first meeting is scheduled to be held Wednesday evening, April 27th. A record is to be kept of each member's work and the progress of the class will be kept in step with that of the classes at the other plants so that men transferring from one plant to another will have no difficulty in continuing with the work.[102]

This policy was implemented throughout the Big Creek system. The 1927 *Annual Report* notes that the number of employees enrolled in study programs increased from 52 percent in 1926 to

[99] "Contented Labor," *Edison Partners*, 6.
[100] Employees on the construction jobs were hired through the Southern California Edison Construction Department, while the operating employees were employed by the Big Creek Division (later the Northern Hydro Division) of the Power Generation Department.
[101] Southern California Edison, *1927 Annual Report*, 27. Similar figures are reported in the 1928 and 1929 annual reports.
[102] O.C. Bangsbury, "Weekly Letter Report, B.C. 3, April 16, 1927," 2, in Archive Room, Big Creek Powerhouse 3.

68 percent in 1927.[103] At the same time, recruitment of new employees seems to have improved: the 1928 Divisional Report noted that "a number of high grade men have been sent in" but also that "the labor turnover, with this class of men, will be somewhat greater… especially college men, are not satisfied to remain as plant operators."[104] The Big Creek management faced a dilemma: intelligent and educated employees were needed to staff the complex powerhouses, but these same people could also find jobs elsewhere in less isolated places than the mountains around Big Creek.

Edison did make efforts to provide amenities and community-building measures to encourage employees to stay. For instance, losses were anticipated in the commissaries and cookhouses provided for the construction workforce, and the total losses averaged into the cost of construction of the powerhouses.[105]

Though many single men remained in bunkhouses, married men and supervisors often became eligible to live in one of the cottages constructed in Big Creek and at the camps close to the lower powerhouses.

> Their pretty cottage homes, which surround the powerhouses, are equipped with everything that is newest and best in sanitation and electrics. Some of the powerhouse colonies have lawn tennis courts and swimming pools; new books are carried to the powerhouse people from nearby public libraries at frequent intervals, and every now and then a welfare agent comes along with a portable motion picture machine, and shows them the latest "movies."
>
> To "The People Who Live in the Powerhouses" the radio has been a great blessing. They get the news of the day and night as it is read by the broadcasters in the big newspaper offices, and the listen to the entertaining lectures and beautiful concerts which the radio service of the city newspapers is now providing.[106]

The company also sponsored a social institution, the Edison Clubs, which were located at each powerhouse and in Big Creek.[107] The Edison Clubs sponsored dances, kept a library and newspaper subscriptions, and organized other events such as card parties, picnics, film screenings, and miniature golf outings. Outside of Big Creek town, the powerhouses also maintained small commissaries. The clubs were maintained by a combination of employee dues (.50 per month in 1931) and company subsidies.[108]

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[103] Southern California Edison, *1927 Annual Report*, 29.
[104] Southern California Edison, *1928 Annual Report*, 13.
[105] In Arthur Kelley's unit cost developments and price books for the Big Creek plants, these losses are included in the cost of materials and labor, suggesting that the company saw these subsidies as a routine construction expense.
[106] "People Who Live in the Powerhouses," *Edison Partners*, 11.
[107] For more discussion of the Edison Clubs and their social role, see Shoup, *Life at Big Creek*, 6-8.
[108] Edison Club #28, "Minutes of regular monthly meeting, held Thursday, October 5th, 1933," in Archive Room, Big Creek Powerhouse 2/2A; Edison Club #21, "Minutes, Regular Meeting, December 3, 1931," in Archive Room, Big Creek Powerhouse 1.

Big Creek in Context
Between late 1911, when construction began on Big Creek Powerhouse 1, and 1929, when Powerhouse 2A was completed, the Big Creek region was transformed from inaccessible wilderness to an industrial landscape and company town intimately connected to the economy of greater Los Angeles. Each phase of the great expansion was marked by pioneering technical achievements in transportation, dam building, tunnel driving, powerhouse design, and transmission line construction. In the process, a community developed that was marked by a combination of pioneer spirit and corporate paternalism. For many who worked in Big Creek, such as David Redinger, the experience was one that defined their lives.

TECHNOLOGY AND STRUCTURAL DESIGN

Structural Design, Powerhouse 2
Exterior
Powerhouse 2 is a five-story reinforced concrete and steel structure, which measured 171' long, 85' wide, and 104' high on initial construction, and 227' long after its extension in 1925. The walls and floors are constructed of reinforced concrete and supported by steel columns, encased in concrete. The columns are spaced at 14' intervals and form pilasters on the façade. The roof is supported by 6-piece steel trusses in line with the columns.

View CA-167-F-43 shows an elevation of the plant after its extension in 1924. View CA-167-F-1 shows the plant in its context, while Views CA-167-F-2 through CA-167-F-8 show external elevations of the structure in late 2009.

The arrangement of windows follows the structural frame and corresponds to the arrangement of floors in the building. On the north façade, each bay between pilasters has four window openings. The lower two correspond to the generating floor (which spans the height of the first three floors), and the upper two to the fourth and fifth floors. On the south façade there are window openings only on the fourth level. On the fifth floor of the south façade, a canopy projects behind the building (Views CA-167-F-6 and CA-167-F- 7).

The first, second, fourth, and fifth floor windows feature a central double-hung sash in the lower central part of the window opening, with fixed sash on the sides and top. The third-floor windows, at the top of the generator room, feature three sash panels, each of which open around a horizontal central pivot, presumably so that they could be operated mechanically from the generator floor below. All window sash is framed in wood. Views CA-167-F-2 and CA-167-F-3 show the window openings in the north façade. View CA-167-F-10 shows the windows from inside the main generator room.

The roof has a slight pitch to front and rear for drainage, forming a gable at the east and west elevations, and was equipped with gutters and downspouts of sheet metal (Views CA-167-F-4, CA-167-F-8. On top of the roof were also located two lightning arrester towers, two horn gap towers, and two A-frame towers.[109] With the towers, the building reached a total height of 138'.

Interior Space

The interior space of the building is shaped by the placement of the structural columns. Two lines of columns spaced 14' apart run the length of the building and support the upper floors. The columns establish two discrete areas of interior space. Between the south wall and the first row of interior columns is the main generator floor, a space 43'-9" wide and 45' high running the length of the building and spanning the height of the first three floors. The first and second rows of columns are 20' apart, and another 18' space separates the second row of columns from the north wall. The plant is thus divided into a 'front' or generator portion of the building and a 'rear' portion that housed offices, control rooms, and switching equipment.

On construction in 1913, thirteen files of structural columns 14' apart were constructed, giving the plant a total width of 171'. Since the plant was designed for expansion, the east end of the plant was a temporary wall, framed in timber and covered in stucco on metal lath. On original construction, the I-beams at the level of the fourth and fifth floor ceilings were left projecting outside the east side of the building. The Stone and Webster plans for the building show space for the addition of three more files of structural columns, for a total of sixteen. However, when the plant was extended in 1921, four files of columns were added for an additional 56' of length. Only one of these was completed to the full height of the building; the others were completed only to the height of the third floor (see CA-167-F-2).

Basement

The basement of Powerhouse 2 sits on a foundation of reinforced concrete extending to bedrock. The front or southern part of the basement holds the pits for the turbines and generators. The oil pump room is located in the front center of the building, between the pits for Units 3 and 4 and those for Units 5 and 6. In the rear, or northern, portion of the basement were located the penstock entries, transformer oil tanks, the oil treating room, ductwork, and the exciter tailraces. Views CA-167-F-25 and CA-167-F-26 show the basement oil pressure room with lubricating oil storage tank and oil filter.

First (Generator) Floor

The front or southern part of the first floor is the main generator floor, which reached a height of 45' and ran the length of the building. Two of the four generating units were installed at the west end of the building in initial construction, while a temporary wooden floor was installed over the eventual location of Unit 3. Views CA-167-F- 9 and CA-167-F-12 show overviews of the generator floor.

In the northern or rear portion of the building, transformer banks were located directly behind the generators, each with three transformers. The banks were separated from each other by barrier

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109 Arthur R. Kelley, *Price Book Accompanying Valuation of Electric Properties, Southern California, Edison Big Creek No. 2 Development, Including Huntington Lake Reservoir, December 31, 1922*, Federal Project 67 Appendices, 250, in Plant Accounting Department, Southern California Edison Company, Rosemead, California.

walls consisting of galvanized iron on shiplap.[110] On initial construction in 1913, space was set aside for a third transformer bank behind the eventual location of Unit 3, but was initially used only to house one spare transformer of the same type. The transformer banks, like the generator room, spanned the first three floors to a height of 45'. View CA-167-F-13 shows the former Unit 3 transformer bay, now used as a welding shop.

At the centerline of the building, between transformer banks, were located the Unit 3 and 4 exciters and exciter wheels. View CA-167-F-11 shows the Unit 3 right header governor pressure regulator. Behind the transformer banks along the north wall of the building were located the oil storage room and the generator rheostats. The two agitators were located immediately behind and in a line with the exciters. Behind the Unit 5 transformer bank, at the northeast corner of the building, was located the battery room.

Along the roof of the generator room ran an 85-ton capacity Cleveland Electric traveling crane, which allowed installation and movement of equipment within the plant.[111] The crane is visible in View CA-167-F-10.

Second Floor

Because of the height of the generator room, the second and third floors were partial floors, located only in the rear (southern) part of the building.

The second floor is 12' high and consists of the control room at the center of the completed building and a gallery along the rear (south) wall of the building (Drawing 12075). The control room, which was originally reached by two staircases from the generating floor (since removed), contained the switchboards and allowed operators to see the entire generating floor through the windows. In the gallery, an office and lavatory were located behind the control room, while the eastern portion was occupied by the 6.6kV bus equipment. Each bus was installed in separate chambers with 12" thick concrete walls.[112] Views CA-167-F-14 through CA-167-F-16 show interior second floor spaces.

Third Floor

The third floor consisted of a storeroom above the control room and a gallery along the rear (north) wall of the plant. The 6.6kV oil switches were located in the gallery, allowing switching for station power, the transformer banks and the generators. Behind the storeroom at the centerline of the completed building were located the exciter starting switches and a staircase leading down.

Views CA-167-F-17 and CA-167-F-18 shows the south gallery on the third floor third floor corridor. Views CA-167-F-19 through CA-167-F-20 show the electrical room on the third floor.

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[110] Kelley, *Valuation*, 167.
[111] Kelley, *Valuation*, 78.
[112] "The 150,000-Volt Big Creek Development-II," *Electrical World*, January 10, 1914, 85.

Fourth and Fifth Floors
The fourth and fifth floors were full floors occupied the entire area of the building. Each floor contained two sets of six General Electric 150kV oil switches and the associated high tension bussing equipment, for a total of four sets of high tension switches. This duplication allowed each transformer bank to be connected to either the west or east transmission lines.

The fourth floor was 26'-3" high, with parallel rows of equipment running the length of the building. The high tension bus room occupied the southern or front portion of the floor, the 150kV oil switches stood in a line in the center aisle, and two sets of 150kV lightning arresters were place along the north wall, connected to the lightning arrester towers on the roof. The oil switches were partially enclosed by concrete walls.[113] Two barrier walls 12' high consisting of 2" of plaster on metal lath ran the length of the building, separating the oil switches from the high-tension bus room and from the lightning arresters. These walls would serve to impound oil in case of accidental discharge from the oil switches.[114] The lightning arrester rooms were located on the lower fourth floor, which extended 9' below the level of the upper fourth floor, giving the rooms a total height of 35'-3".

Views CA-167-F-21 and CA-167-F-22 show the north (front) gallery of the fourth floor. Note the removal of the busses from this area, and the continued presence of banks of circuit breakers.

On the fifth floor, the area occupied by the lighting arresters on the fourth floor was occupied by the transmission lines, which exited the building under the 14' canopy extending from the northern façade of the building.

Structural Design, Powerhouse 2A
Powerhouse 2A is a one-story reinforced concrete and steel structure, 210' long, 66' wide, and 60' high. A 27' x 107' extension on the north side of the main structure housed the low-tension busses and transformers. An adjacent outdoor platform 23' wide and 75' long supported the high-tension busses and circuit breakers (see CA-167-F-30).[115]

Façade and Roof
The north and south facades feature ten pilasters between the corners of the building, spaced 17' from centerpoint to centerpoint and corresponding to the structural columns. The roof is slightly peaked, forming an undecorated gable on the west end beneath a slightly overhanging cornice. Eleven slightly recessed window bays span the north and south facades. On the front (north) façade each bay has two windows separated by a recessed, undecorated spandrel; the south façade has the same configuration but with recessed panels instead of windows (CA-167-F-31). The eastern end of the building has two pilasters set between the corners of the building, framing three recessed window bays. In each bay the lower window is 19'-6" high and is separated from the upper window by a recessed panel 9'-5" high. The upper window is 16'-10½" high.

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[113] "150,000-Volt Big Creek Development-II," 86.
[114] Kelley, *Valuation*, 167.
[115] Kelley, *Unit Cost Repair*, 20.

The low-tension bus building is 28'-11" high, and extends in a line from six structural columns at the center of the main building (View CA-167-F-29). It has a flat roof edged with a stringcourse with one pendant dentil at the centerpoint of each column. On the north façade, an open colonnade of three square columns is framed by two window bays. The east and west facades each have one window bay with one narrow and one larger window opening. The two low-tension busses were separated in the bus room by 2" cement plaster on metal lath partitions.[116]

A concrete platform 23' wide and 75' long extends north side of the low-tension bus building and supports the transformers and high-tension bus equipment. This platform extends over a portion of the forebay and the tailrace exits, and is supported over the water by five square columns.

The roof of the main structure is slightly peaked and has an undecorated gable at the north and south ends, with a slightly projecting frieze below. The steel truss roof of the main structure and the low-tension bus room were originally covered with Pabco special composition roofing, with sheet copper for the flashing and parapet wall caps.

A corridor 20'-9" wide connects Powerhouses 2 and 2A and forms the main entrance point to the combined plant. This entrance is reached by a steel truss bridge that spans Big Creek.

Sash

The windows of Powerhouse 2A are a grid of nine wood-framed sash panels with the upper row fixed and the lower two rows mobile, pivoting outward on the topmost stiles. The fixed sash used Simplex hardware, while the moving sash was opened with Payson Superior sash operators. Sash is framed in wood.[117]

Plan and Floors

The interior of Powerhouse 2A is a single large generator room without internal partitions, except for one between the main generator floor and the open porch that housed the switching equipment. Since control is provided from Powerhouse 2 and switching equipment was located outside, there was no need for multiple floors or rooms inside the plant. The generating units were equally spaced on the main generating floor.

The floor finish in the plant consisted of a 1" covering of 1:1:2 mix concrete combined with a Lithochrome color hardener. The plant was originally painted on the walls and ceilings with two coats of Fuller "Preservo" brand cold water paint. Fuller "Pure Prepared Paint" was used on the crane runway girders, roof trusses, sash, frames, floor plates and gratings, and sash operating mechanisms.[118]

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[116] Kelley, *Unit Cost Repairs*, 91.
[117] Kelley, *Unit Cost Repairs*, 90.
[118] Kelley, *Unit Cost Repairs*, 98-99.

Mechanicals and Operation

General

Hydroelectric plants such as Big Creek Powerhouse 2 and 2A convert the mechanical force of falling water into electrical energy through electromagnetic induction. Water flows through long tubes known as penstocks and is then directed through a nozzle onto the buckets of the turbines, causing them to rotate. The turbines are directly connected to the generator shaft, causing it to turn. A governor is attached to each wheel, allowing the operator to control the speed of the wheel by reducing or increasing water flow against the buckets.

The generator consists of two magnetized copper coils, one rotating (rotor) and the other stationary (stator). To generate power, the rotor coils must be energized by the input of direct current (DC) from an exciter (a separate motor or generator), which produces a magnetic field. The rotation of the magnetized rotor field against the stator windings produces electromagnetic flux and induces alternating current (AC) in the stator's output terminals.

Current from the generators is sent through step-up transformers, which increase the voltage to a level desirable for transmission, and then into transmission lines leaving the plant. Between the generator and transformer, low-tension bus rooms allow electric current from the generators to be sent to different banks of transformers. Between transformers and transmission lines high-tension bus rooms allow current to be switched between different transformer banks and transmission lines. At Powerhouse 2, parallel sets of generating, bussing, transforming, and transmission equipment allowed generation to continue even when individual elements of the system must be taken offline for maintenance or due to mechanical problems. Powerhouse 2A, by contrast, used a single high-tension bus and a single transmission line.

Despite the complexity of the plant, the equipment in Powerhouse 2 was procured from a limited number of suppliers. The Allis-Chalmers division of I.P. Morris and Co. (Milwaukee, Wisconsin) supplied almost all of the hydraulic equipment in Powerhouse 2, including nozzles, needles, main turbines, exciter turbines, and governors. The electrical equipment for Units 3, 4, 5, and 6, including the generators, exciters, rheostats, transformers, switches, and busses, was manufactured by Westinghouse Company. Powerhouse 2A used a mix of Allis-Chalmers and Pelton equipment on the hydraulic side, and a mix of Westinghouse generators and General Electric transformers on the electrical side.

Hydraulic Features, Powerhouse 2

Penstocks, Valves, and Nozzles

The penstocks for Units 3 and 4 were manufactured by Mannesman Rohrenwerke of Düsseldorf, Germany, and Willamette Iron and Steel of Portland, Oregon. Each section is 26' long, and narrows from 42" diameter and 3/8" thickness to 24" diameter and 1" thickness. Eight hundred' behind the powerhouse, each pipe divides into two 26" pipes each leading to a 24" hydraulically operated valve. The valves, manufactured by Allis-Chalmers, are designed to tolerate pressures up to 1,000 psi. On the other side of the valves are located adjustable nozzles which direct water at the turbine buckets. When fully open, these nozzles were designed to emit a jet of water 5½" wide at 350' per second.[119]

Turbines

The generating units at Powerhouse 2 are double overhung horizontal impulse turbines of the Pelton type. In an impulse turbine, the kinetic energy of the water as it exits the nozzle is absorbed by the buckets of the turbine and transformed into momentum (impulse), leaving the water with diminished velocity. A "double overhung" turbine is one in which two separate waterwheels, one on each end of the shaft, provide the motive force for the generator. Placing one waterwheel on each side produces an even torque on the generator shaft.

The turbines for Units 3 and 4 were manufactured by Allis-Chalmers and were rated for 20,000 horsepower (10,000 from each wheel) at 1680' of head and 375 rpm. Each wheel has twenty-one buckets and is 94" in diameter. Units 3 and 4 bear Allis-Chalmers serial numbers 340 and 341, and were purchased on Contract No. 12699. Installed by Stone and Webster in 1913, each waterwheel assembly cost $29,328.24 including the shaft, bearings, runners, needles, nozzles and housings.[120] As *Electrical World* noted in its profile of the plant, "apart from operating under one of the highest heads thus far developed, these wheels are the largest of their type ever built."[121] Each pair of wheels along with its shaft weighed over 100 tons when installed. Unit 5 used 22,500hp Pelton impulse wheels operating at 375rpm under 1680' of head and was installed in February 1921.[122]

Governors

The governor was used to control the speed of the turbines by regulating water flow. Units 3 and 4 were equipped with Allis-Chalmers, Size 2 Oil Pressure Type automatic turbine governors. The governors controlled the needle valves at the end of the intake nozzles, allowing variation of the flow of water against the turbine buckets. In this way the turbine could rapidly change speed in response to fluctuations in load and automatically limited the speed of the generator so that it could not supply more than a predetermined amount of power. The turbines were also provided with relief valves and hand controls in case the automatic governor failed.[123] The current arrangement of governors can be seen in View CA-167-F-09.

Exciter Wheel

The Unit 3 and 4 exciters in Powerhouse 2 are connected to a single Allis-Chalmers Type B-1 350hp impulse turbine, which rotates at 750 rpm under an effective head of 1900'. The wheel for exciter Units 3 and 4 bears Allis-Chalmers serial numbers 365 and 366 and cost $2,279.74, inclusive of housing, buckets, needles, and nozzles. The exciter wheel was also equipped with its own governor. At Powerhouse 2 this was an Allis-Chalmers Size 0 Oil Pressure Type Turbine Governor.[124]

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119 Jessup, "High-head Hydroelectric Power Development," 205.
120 Kelley, *Unit Cost Development*, 155.
121 "150,000-Volt Big Creek Development-I," 36.
122 Kelley, *Unit Cost Development*, 175.
123 Kelley, *Unit Cost Development*, 161; "150,000-Volt Big Creek Development-I," 36.
124 Kelley, *Valuation*, 160; Kelley, *Unit Cost Development*, 68; Kelley, *Price Book*, 70.

Oil Pump Wheel
The central oil pressure pump for Powerhouse 2 was operated by a 25 HP Allis Chalmers Impulse Wheel, which operated two pumps. Each pump was connected to the water wheel by a clutch, while each flange was also connected to one of two 35hp, 220V, 715 rpm Allis Chalmers Induction Motors. This enabled the pump to be operated by either water power or electrical power depending on the needs of the plant. The oil was used to lubricate the operating valves and cylinders of the governors and the main bearings of the generators.[125]

Tailrace
Water exits the plant into the forebay through a short tunnel called a tailrace. The Judson Manufacturing Company of Oakland, California, built the steel tailrace linings for Units 3 and 4, while the Lacy Manufacturing Company built those for Unit 5.

Spare Parts
A variety of spare parts were furnished for the hydraulic machinery after initial construction in 1913. These included three needle tips, two nozzle tips, one set wheel buckets and one cross-head for main wheels; two nozzle tips, two needle tips and one set wheel buckets, one regulating valve, and two sets of metal packing rings for main governors.[126]

Hydraulic Features, Powerhouse 2A
Penstocks, valves, and nozzles
Water was supplied to Powerhouse 2A through a single penstock, 6,850' long and 9' in diameter at the top of the grade, which drew water from Shaver Lake.[127] The plant used a static head of 2,418', one of the highest in the United States at the time of construction. The upper 1,858' of the penstock were of riveted steel, supplied by Western Pipe and Steel of San Francisco. The 3,042' of the central section was banded, forge-welded pipe from the Ferrum Company of Poland. The lowest section, of forged seamless pipe, was manufactured by Midvale Steel Company (Nicetown, Pennsylvania) and Bethlehem Steel Company (Bethlehem, Pennsylvania). Above the plant the penstock splits twice to yield four 34" lines, which enter the north wall of the plant at a 30 degree angle, the same angle at which water from the nozzles strikes the turbines.[128] The penstocks can be seen entering the building in View CA-167-F-38 and inside the building in Views CA-167-F-36 and CA-167-F-37.

Turbines
Powerhouse 2A has two generating units, both double-overhung impulse wheels with a 56,000 hp rating. Unit 1 was purchased from Allis-Chalmers (Milwaukee, Wisconsin), for $200,595.27 including nozzles, bearings, baffles, and other fittings. Unit 2 was purchased from the Pelton Water Wheel Company of San Francisco, and cost $151,205.95.[129] Both were designed to meet the same technical requirements, although the manufacturers were offered bonuses for

[125] Kelley, *Price Book*, 167; "150,000-Volt Big Creek Development-I," 36.
[126] Kelley, *Valuation*, 73.
[127] "Powerhouse No. 2A," *Electrical World*, 425.
[128] "Two 56,000-Hp. Impulse Units Utilized 2,418-Ft. Head at Big Creek 2A," *Electrical West*, November 1, 1928, 258.
[129] Kelley, *Unit Cost Report*, 38.

efficiencies above the basic requirements.[130] View CA-167-F-35 shows the generator floor from above, while views CA-167-F-32 through CA-167-F-34 show it from ground level.

The turbines were designed for operation at 250 rpm for generating 50-cycle power, but could be converted for operation at 300 rpm in order to supply 60-cycle power

> by changing the bucket rims, substituting a rim of smaller diameter for the higher speed operation. Removable 'distance blocks' are provided so that the entire unit can be lowered to a point where the water jet from the nozzle will impinge properly upon the buckets of the smaller wheel.[131]

Governors

The governors for each unit in Powerhouse 2A were provided by the respective companies: the Unit 1 governor from Allis-Chalmers and the Unit 2 Governor from Pelton.[132] The Unit 1 left header governor is visible in View CA-167-F-39 and the Unit 2 right header governor in View CA-167-F-41.

Electric Features, Powerhouse 2

Generators

In the initial construction of Powerhouses 1 and 2, Pacific Light and Power purchased electrical equipment from both Westinghouse and General Electric. Powerhouse 1 used generators and transformers from General Electric, while Powerhouse 2 used Westinghouse equipment. In Powerhouse 2, the Unit 3 and 4 waterwheels powered Westinghouse AC generators operating at 17,500 kilovolt-amperes (kVA) and 6600V at 375 rpm.[133] These units bear Westinghouse serial numbers 1100596 and 110595.[134] By the end of 1922 Units 3 and 4 had been rewound to increase their capacity to 20,000 kVA. Unit 5 was also rated for 17,500 kVA and bears Westinghouse serial number 2377289.[135] View CA-167-F-9 shows the generator units in late 2009.

Exciters

As noted above, the exciters energize the magnetic field in the generator rotor, which as it rotates induces electric current in the stator. Two exciters were installed in initial construction, both connected to a single impulse wheel (see 'Exciter Wheel' above). The other exciter was connected through a flanged coupling to a Westinghouse 300hp induction motor, allowing both hydraulic and electrical excitation. The Units 3 and 4 exciter generators were Westinghouse models rated for 200kW and 250V at 720rpm, bearing Westinghouse serial numbers 1100601 and 1101365.[136]

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[130] "Two 56,000-Hp. Impulse Units," 261.
[131] "Two 56,000-Hp. Impulse Units," 259.
[132] Kelley, *Unit Cost Report*, 39.
[133] A volt-ampere is the product of voltage and current. In direct current (DC) systems kilovolt-amperes are equivalent to kilowatts. In alternating current (AC) systems, however, voltage and current are sinusoidal and may be out of phase, yielding less power (fewer kilowatts).
[134] Kelley, *Unit Cost Development*, 188.
[135] Kelley, *Unit Cost Development*, 265.
[136] Kelley, *Unit Cost Development*, 224-225.

Low-Tension Bus
The Powerhouse 2 generators fed current at 6.6kV into the low-tension bus room, originally located on the second floor. The buses were controlled from the low-tension oil switch room on the third floor, which used General Electric K-3 6.6 kV oil switches. Two complete sets of bus equipment were initially provided, allowing current from either generator to be sent to either bus.[137]

Transformers
On initial construction, two banks of three transformers were provided in Powerhouse 2, plus a spare transformer that was placed in the area where Unit 3 would later be installed. The transformers were 5833 kVA, 50 cycle, and supplied by Westinghouse. Oil insulated and water-cooled, the transformers converted the 6.6kV from the generators to the 150kV used for transmission on the Big Creek lines prior to 1923. The initially installed transformers were Westinghouse serial numbers 309994-309996 (Bank 1); 309997, 309998, 310000 (Bank 2); 527896-527898, and 309999 (spare).[138]

High-Tension Bus
From the Powerhouse 2 transformers, the 150kV current arrived in one of the high-tension bus rooms on the fourth or fifth floors. The switches for each high-tension bus were located on the same floor, and were General Electric 150kV oil switches of the K-21 type. Two complete sets of bus equipment were provided for each transformer bank, for a total of four sets. This allowed either transformer bank to feed power into either of the two transmission lines leaving the plant.[139]

Transmission Lines
Two transmission lines were constructed in the Big Creek initial development, and traveled 241 miles to the Eagle Rock substation in Los Angeles. Called the "East" and "West" lines, each line entered the plant at two points, one at the fourth floor high-tension bus, and one at the fifth-floor high-tension bus. The leads of the transmission lines were sheltered as they left the plant by a canopy projecting 14' from the north façade of the powerhouse.

Lightning Arrester and Horn Gap Towers
The plant as originally constructed was furnished with two lightning arrester towers and two horn gap towers on the roof. These towers served to ground arcs or lightning that might touch the power line. The lightning arresters grounded charges into tanks located on the lower fourth floor of the powerhouse structure.[140] The towers extended approximately 30' upward from the roof of the powerhouse.

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[137] "150,000-Volt Big Creek Development-II," 85.
[138] Kelley, *Valuation*, 141.
[139] Kelley, *Unit Cost Development*, 309; "150,000-Volt Big Creek Development-II," 85-86.
[140] Kelley, *Unit Cost Development*, 318.

Electric Features, Powerhouse 2A

Generators

At the time of their construction the two 56,000-hp generating units of Big Creek 2A were the largest capacity high-head units ever constructed.[141] Both generators in Powerhouse 2A were purchased from Westinghouse, rated at 45000 kVA, 11kV, 250 RPM and bearing the manufacturer's serial numbers 4705524 and 4705525.[142] The generators were manufactured in Pennsylvania and assembled on site.[143] The total weight of each generator unit was 273 tons, 186 tons of which was in the generator rotor and shaft. Unit #1 was put into service on August 6th, 1928, and Unit 2 on December 21, 1928.[144] Views CA-167-F-32 through CA-167-F-41 show the generators from several angles.

Exciters

Both units in Powerhouse 2A used Westinghouse exciters, rated at 340kW, 250V, and bearing serial numbers 4705853 and 475524.[145] These exciters were of the "pilot-exciter" type, where the primary exciter depends for its own field excitation on a second small "pilot" exciter with a 4kw rating. Both main and pilot exciters were mounted in tandem on an extension of the generator shaft. This arrangement allowed much more rapid generator startup: the Powerhouse 2A units could pick up from no load to full load in only 1.6 seconds.[146] The Unit 1 exciter is visible in View CA-167-F-37.

Low-Tension Bus

In Powerhouse 2A, a single low-tension was bus connected to the two generators through parallel sets of Westinghouse Type O-44 oil circuit breakers, which traversed the low-tension bus building to connect to the outdoor transformers.[147]

Transformers

Powerhouse 2A used four General Electric Type WC 30,000kVA oil-cooled, outdoor-type transformers. The high-voltage ends were grounded at 220kV in Y, and the low-voltage ends were grounded in delta at 11/13.2kV. They bore the manufacturer's serial numbers 3195649 through 3195652.[148] The transformers stood on the outdoor platform above the tailrace. Like the generators, they were designed for operation at either 50 or 60 cycles.[149] News articles noted that this outside design was the main factor that enabled the Powerhouse 2A building to be almost 50' shorter than Powerhouse 2.

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[141] "High-Speed Field Excitation for 45,000-Kva. Big Creek 2-A Generators Will Aid System Stability," *Electrical West*, November 1, 1928, 263.
[142] Kelley, *Unit Cost Report*, 43.
[143] Kelley, *Unit Cost Report*, 184.
[144] Southern California Edison, "Memorandum," 3.
[145] Kelley, *Unit Cost Report*, 43.
[146] "High-Speed Field Excitation," 265.
[147] "High-Speed Field Excitation," 265.
[148] Kelley, *Unit Cost Report*, 58.
[149] "Powerhouse No. 2A on Big Creek in Operation," *Electrical West*, 266.

Transmission Lines
Powerhouse 2A was connected into the main Big Creek system by a separate transmission line from Powerhouse 2. A single oil circuit breaker connected the transformers to a short transmission line leading to the main 220kV bus at Big Creek 3.[150]

Control and Maintenance, Powerhouse 2
Control room
The main switchboard was also purchased from Westinghouse and included 15 panels on which switches and gauges were mounted.[151] As *Electrical World* noted:

> The main switchboard, which is of the bench type, is located in a gallery in the center of the operating room, immediately above the exciter bay, and by remote control it governs the generators, transformers, switch operation and auxiliary control of governors and exciter motors.[152]

The exciters and generator field boards, however, were located in the first floor exciter bay, while a small upright switchboard in the second floor gallery controlled the storage battery and station light and power functions.

Crane
The generator room was supplied with a traveling crane to move machinery within the plant. Supplied by Cleveland Electric, the crane was electrically powered with a capacity of 85 tons. It had a span of 40' and a run of 168'-4".[153] The crane is visible in CA-167-F-10.

Control and Maintenance, Powerhouse 2A
Control Room
Powerhouse 2A is operated from the main control room in Powerhouse 2.

Crane
The generator room in Powerhouse 2A was served by two 150-ton capacity traveling cranes manufactured by Western Manning, Maxwell, and Moore Incorporated of Muskegon, Michigan.[154] The crane can be seen in CA-167-F-33.

Alterations and Additions
Powerhouse 2, like the other powerhouses in the Big Creek system, is a working industrial facility in continuous operation since its construction in 1913. As such, it has been subject to regular maintenance and overhaul of equipment. This section details only major modifications to the plant.

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150 "High Head and Large Units," 991.
151 Kelley, *Valuation*, 195.
152 "150,000-Volt Big Creek Development-I," 38.
153 Kelley, *Valuation*, 78.
154 Kelley, *Unit Cost Report*, 100.

The third generating unit (No. 5) came online in April 1921. Construction required the removal of the temporary wooden floor over the generator pit, the installation of tailrace linings, and the removal of the temporary end of the building. Like Units 3 and 4, Unit 5 was a Westinghouse 17,500 kVA, 6.6kV generator.[155]

Powerhouse 2 was completed to its planned dimensions with the installation of Unit 6 in April 1925. Installation of this fourth unit required the extension of the powerhouse by 56' (four 14' column lengths) for a total length of 227'. Only part of the extension, however, was constructed to the full height of the building. As the *Journal of Electricity* explained, "above the fourth floor line it will be necessary to make only a 14-ft. extension as the additional bus and switching equipment takes up less room than the generating unit."[156] Like the others, Unit 6 was a Westinghouse rated at 17,500kVA and 6.6kV at 375rpm.[157]

Powerhouse 2 saw relatively few other modifications in the first decades of operation. The generator coils of Units 3, 4, and 5 were rewound in 1930 and 1931.[158] Although most of the Big Creek system (including Powerhouse 2A) had switched to or been constructed for 220kV transmission, Powerhouse 2 continued generating at 150kV until 1949, when the fourth and fifth floor bussing equipment was removed. The 4th floor, however, continued to house low-tension busses after the conversion to 220kV operation. Finally, the late 1940s and early 1950s saw the conversion of generators in the plant to 60-cycle operation, which required installing different bucket sizes on the waterwheels.[159]

At Powerhouse 2A, transformers and switching equipment have been upgraded, and parts replaced. Generator Unit 1 was rewound in 1949 for generation at 50,000kVA and 13.2kV, and was repaired in 1931, 1945, 1966, and 1973. In 1950, Generator Unit 2 was also rewound in for generation at 50,000kVA and 13.2kV, and was repaired in 1941, 1957, 1959, and 1981.[160]

CONTEXT AND SIGNIFICANCE

Preservation

Environmental Setting

Big Creek 2/2A retains integrity of setting. The powerhouse buildings are located on the south bank of Big Creek, approximately 3.5 miles west of Big Creek town. Viewed from the north, the buildings rise directly from the creek with, forested hills rising steeply behind them. Besides the visible line of the penstocks, little other development is evident in the vicinity. The setting of the plants appears as it did when the plants were built, although forest cover in the area is today considerably thicker than it was in the 1920s.

[155] Southern California Edison, "Memorandum," 2.
[156] "Big Creek No. 2 Power House Being Extended," 212.
[157] "New Unit at Big Creek No. 2 Placed in Operation," *Journal of Electricity*, April 15, 1925, 297.
[158] Southern California Edison, "Memorandum," 2.
[159] Don Dukleth, "Changes to Powerhouse 2-2A after 1929," memorandum supplied to consultants, based on Southern California Edison Northern Hydro Division Annual Reports.
[160] Southern California Edison, "Memorandum," 2-3.

Structural/Façade
From outside, Powerhouse 2 appears much as it did on completion of Unit 4 in 1925 and preserves the appearance intended by the original designers. Structurally, Powerhouse 2A retains its appearance as built in 1928.

Window Sash and Doors
The window sash in Powerhouses 2 and 2A is original. While broken panes have been replaced, most lights remain in their original wooden frames throughout the powerhouses. The original wooden external doors, however, have been replaced with metal equivalents since initial construction.

First (Generator) Floor, Powerhouse 2
The turbines, generating units, and generating room overall appear as they did on first installation. Routine maintenance has been performed on the equipment, including replacement of turbine buckets and rewinding of generators. However, the turbines, generators, and many gauges remain in their original casings. As a result, the generator floor looks much as it did on original installation of the equipment. The rear portion of the first floor housed the transformers, the oil storage room, and the station service transformers. The power transformers were moved to an outside switchyard around 1923. The former western transformer bay is presently used as a machine shop.

Second Floor, Powerhouse 2
The control room has been substantially modified from its original appearance by the replacement of the original boards, the removal of the external stairways, and the addition of computers and other modern office equipment.

Third - Fifth Floors, Powerhouse 2
Transformers and bussing equipment, originally located on the upper floors, were moved to an outside switchyard in 1930, leading to the removal of the equipment in the original bussing and switching rooms. Today, the fourth floor is used to house the station light and power transformers, and the fifth floor is used for storage.

Generating room, Powerhouse 2A
The generating room in Powerhouse 2A looks much like it did in 1928. The turbines and generators use substantially the same equipment, and other aspects of the layout of the building remain very similar.

Low-tension Bus Porch and Transformer Deck, Powerhouse 2A
The low-tension bus porch and outside transformer deck at Powerhouse 2A have been modified due to technological upgrades. The original transformers have been removed and replaced by a transformer and bus unit that sits inside the low-tension bus porch.

The excellent state of preservation, continuity of use, and integrity of setting appear to present sufficient integrity to convey the significance of the structure.

Significance

Big Creek Powerhouse 2 and 2A are NRHP-eligible structures of statewide significance, part of a district of national significance. As the discussion above suggests, the powerhouse retains substantial structural and functional integrity.

At the time of its construction the plant, along with its twin Powerhouse 1, was one of the highest-head hydroelectric developments in the western United States. The waterwheels and generators were among the largest of their type ever constructed, and the powerhouse was the first in the world to transmit electricity commercially at 150kV. Powerhouse 2A also had the largest wheels and generators then in use on its construction in 1928. The Big Creek system was also the premiere example of the transition from the construction of isolated power plants serving local markets to the construction of large systems integrated with distant energy markets via high-voltage transmission. Powerhouse 2, as one of the first plants in the system, is especially symbolic of this important logistical and technological innovation in the design of electrical transmission and generation systems.

The Big Creek system is also significant in the history of the Los Angeles region. Conceived as a means of powering both residential development and electric railways, power from Southern California Edison's Big Creek plants was instrumental in the rise of suburban development in the region. The system is closely associated with railroad, energy, and development magnate Henry Huntington; with Edison executives and power pioneers A.C. Balch, William Kerckhoff, and George C. Ward; visionary California hydroelectric engineer John Eastwood; and longtime Big Creek manager David Redinger.

SOURCES OF INFORMATION

Research Sites

Archival research for this report was conducted in the following locations:

- Water Resources Library, University of California, Berkeley, California
- Bancroft Library, University of California, Berkeley, California
- Engineering Library, University of California, Berkeley, California
- University of California Northern Regional Library Facility, Richmond Field Station, Richmond, California
- Philadelphia Free Library, Philadelphia, Pennsylvania
- Southern California Edison Collection, Huntington Library, San Marino, California
- Plant Accounting Department, Southern California Edison Company, Rosemead, California
- Northern Hydro Division Headquarters, Southern California Edison Company, Big Creek, California
- Big Creek Powerhouse 1, Big Creek, California
- Big Creek Powerhouse 2/2A, Big Creek, California
- Big Creek Powerhouse 3, Big Creek, California
- Big Creek Powerhouse 8, Big Creek, California

Primary Sources

"The 150,000-Volt Big Creek Development – I." *Electrical World*, January 3, 1914, 33-38.

"The 150,000-Volt Big Creek Development – II." *Electrical World*, January 10, 1914, 85-88.

Bangsbury, O.C. "Weekly Letter Report, B.C. 3, April 16, 1927." In Archive Room, Big Creek Powerhouse 3.

Battey, W.R., George C. Heckman, and J.M. Gaylord. Letter to Mr. B.F. Pearson regarding the Big Creek Number 3 penstock accident, March 19, 1924. In Archive Room, Big Creek Powerhouse #3, Big Creek, CA.

Big Creek No. 1. *Daily Log*. December 1, 1913. In Archive Room, Big Creek Powerhouse 1.

"Big Creek No. 2 Power House Being Extended 56 ft." *Journal of Electricity*, 54 (1925): 212.

Big Creek No. 3. *Floor Log Volume 11 (1926-1927)*. In Archive Room, Big Creek Powerhouse 3.

Big Creek No. 3. *Floor Log Volume 12 (1927)*. In Archive Room, Big Creek Powerhouse 3.

"Big Creek No. 8 Hydro-Electric Unit Completed." *Journal of Electricity and Western Industry*, August 15, 1921, 160.

"Big Creek-San Joaquin Hydro-Electric Project of the Southern California Edison Company." *Western Construction News*, July 10, 1927, 28-36.

"Big Creek Work Nears Completion." *Fresno Morning Republican*, December 2, 1913.

Downing, P.M., O.B. Caldwell, E.R. Davis, W.G.B. Euler, and C.C. MacCalla. "Report of the Sub-committee on Water Development on the Pacific Coast." In National Electric Light Association, *Papers Reports and Discussions, Hydro-Electric and Transmission Sections Technical Sessions, National Electric Light Association Thirty-Eight Convention,* 510-601. San Francisco: National Electric Light Association, 1915.

Dukleth, Don. "Changes to Powerhouse 2-2A after 1929." Memorandum supplied to consultants, based on Southern California Edison Northern Hydro Division Annual Reports.

Eastwood, John S. "Progress Report for 1903-1904 of Right of Way Surveys and Outline Plan for Power Plant No. 1," 1904. In Folder 11, Box 302, Southern California Edison Papers, Huntington Library, San Marino, California.

___________. "Comparative Estimate of Cost of Water-Power Transmission Plant vs. Steam Plant, for W.G. Kerckhoff, President, Pacific Light and Power Company," 1905, Document No. 12871. In History and Information File, Northern Hydro Division Headquarters Library, Big Creek, California.

Edison Club #21. "Minutes, Regular Meeting, December 3, 1931." In Archive Room, Big Creek Powerhouse 1.

Edison Club #28. "Minutes of regular monthly meeting, held Thursday, October 5th, 1933." In Archive Room, Big Creek Powerhouse 2/2A.

"Fire at Big Creek Causes Damage of $10,000." *Fresno Morning Republican,* October 20, 1913.

Fourteenth Census of the United States, Cascada Precinct, Fresno County, California, 1920. On file, University of California at Berkeley.

"High Head and Large Units at Big Creek 2-A." *Electrical West*, November 17, 1928, 989-992.

"High-Speed Field Excitation for 45,000-Kva. Big Creek 2-A Generators Will Aid System Stability." *Electrical West*, November 1, 1928, 263-266.

Hilbert, P.H. to R.B. Lawton. "Big Creek No. 8 Operating Shift Schedule." Memorandum dated February 19, 1926. In File 29-940.1, Archive Room, Big Creek Powerhouse 8.

Jessup, Walter. "A High-head Hydroelectric Power Development in the Sierra Nevada

Mountains, California." *The Wisconsin Engineer* 18 (1914):193-211.

Kelley, Arthur R. *Valuation of Electric Properties, Southern California Edison Big Creek No. 2 Development, Including Huntington Lake Reservoir, December 31, 1922.* Federal Project 67 Appendices, Plant Accounting Department, Southern California Edison Company, Rosemead, CA.

___________. *Unit Cost Development Accompanying Valuation of Electric Properties, Southern California Edison Big Creek No. 2 Development, Including Huntington Lake Reservoir, December 31, 1922.* Federal Project 67 Appendices, Plant Accounting Department, Southern California Edison Company, Rosemead, CA.

___________. *Price Book Accompanying Valuation of Electric Properties, Southern California Edison Big Creek No. 2 Development, Including Huntington Lake Reservoir, December 31, 1922.* Federal Project 67 Appendices, Plant Accounting Department, Southern California Edison Company, Rosemead, CA.

___________. *Unit Cost Report, Big Creek No. 2A Development, as of December 31, 1932.* Federal Project 67 Appendices, Plant Accounting Department, Southern California Edison Company, Rosemead, CA.

Lawton, R.B. to D.D. Morgan. "Operating Force – Big Creek." Undated memorandum, probably 1922. In File 29-939, Archive Room, Big Creek Powerhouse 8, Big Creek, CA.

"Merger of California Hydroelectric Systems." *Electrical World*, December 9, 1916, 1134-1137.

"New Big Creek Unit Penstock Contracts Let By Edison." *Journal of Electricity*, October 1, 1926, 258.

"New Unit at Big Creek No. 2 Placed in Operation." *Journal of Electricity*, April 15, 1925, 297.

"Power House No. 2A on Big Creek in Operation." *Electrical World*, September 1, 1928, 425.

Redinger, David H. "Progress on the Big Creek Hydro-Electric Project, Part I." *Compressed Air Magazine,* December 1923, 720-724.

__________. "Progress on the Big Creek Hydro-Electric Project, Part II." *Compressed Air Magazine,* January 1924, 747-750.

__________."Progress on the Big Creek Hydro-Electric Project, Part III." *Compressed Air Magazine,* March 1924, 803-808.

__________."Progress on the Big Creek Hydro-Electric Project, Part IV." *Compressed Air Magazine,* April 1924, 837-842.

__________."Progress on the Big Creek Hydro-Electric Project, Part V." *Compressed Air Magazine,* September 1924, 989-992.

"Second Unit Installed at Big Creek Plant No. 8." *Electrical West*, July 1, 1929, 38.

Sohier, W. *The Big Creek Project, A History, December 27, 1917*, typescript. In Folder 7, Box 302, Southern California Edison Papers, Huntington Library, San Marino, California.

"Southern California Edison's Advance." *Electrical West*, April 21, 1928, 829.

"Southern California Edison Company to Start 150,000-Kw. Station." *Electrical World*, September 24, 1921, 636.

Southern California Edison Company. *1926 Weekly Letter Reports, Big Creek Powerhouse 2.* In Archive Room, Big Creek Powerhouse 2/2A, Big Creek, CA.

____________. *1927 Annual Report, Big Creek Division.* In History and Information File, Northern Hydro Division Headquarters, Big Creek, California.

____________. *1927 Weekly Letter Reports, Big Creek Powerhouse 2.* In Archive Room, Big Creek Powerhouse 2/2A, Big Creek, CA.

____________. *1928 Annual Report, Big Creek Division.* In History and Information File, Northern Hydro Division Headquarters, Big Creek, CA.

____________. *1928 Weekly Letter Reports, Big Creek Powerhouse 2.* In Archive Room, Big Creek Powerhouse 2/2A, Big Creek, CA.

____________. *1929 Annual Report, Big Creek Division.* In History and Information File, Northern Hydro Division Headquarters, Big Creek, CA.

____________. "Memorandum, Hydro Generation, Northern Division, Generator Winding Data Revised to May 13, 1985." In History and Information File, Northern Hydro Division Headquarters Library, Big Creek, California.

Stone and Webster Construction Company. "Progress of the Big Creek Initial Development: Report to Pacific Light and Power Corporation, January 1, 1913." In Water Resources Library, University of California, Berkeley.

___________. "Big Creek Initial Development 1914." In Water Resources Library, University of California, Berkeley.

"Transmission at 220,000 Volts a Fact." *Electrical World*, May 12, 1923, 1107.

"Two 56,000-Hp. Impulse Units Utilized 2,418-Ft. Head at Big Creek 2A." *Electrical West*, November 1, 1928, 257-262.

"Work Progressing Rapidly on Big Creek No. Three." *Journal of Electricity and Western Industry*, May 1, 1923, 341.

Secondary Sources

Bradley, Betsy Hunter. *The Works: The Industrial Architecture of the United States.* New York: Oxford University Press, 1999.

Federal Power Commission. *Directory of Electric Generating Plants.* Washington, D.C.: Federal Power Commission, 1941

Hay, Duncan. *Hydroelectric Development in the United States, 1880-1940.* Washington, D.C.: Edison Electric Institute, 1991.

Hughes, Thomas P. *Networks of Power: Electrification in Western Society, 1880-1930.* Baltimore: Johns Hopkins University Press, 1983.

Kirker, Harold. *California's Architectural Frontier: Style and Tradition in the 19th Century.* San Marino, CA: Huntington Library, 1960.

Redinger, David H. *The Story of Big Creek.* Los Angeles: Angelus Press, 1949.

Shoup, Laurence H. *"The Hardest Working Water in the World": A History and Significance Evaluation of the Big Creek Hydroelectric System.* Southern California Edison Company, Rosemead, CA, 1987.

___________. *Life at Big Creek Town 1929-1947: Historic Context Statement and National Register of Historic Places Significance Evaluation.* Southern California Edison Company, Rosemead, CA, 1997.

U.S. Department of Energy. *Inventory of Power Plants in the United States, 1981 Annual.* Washington. D.C.: U.S. Department of Energy, 1982.

Whitney, Charles A. "John Eastwood: Unsung Genius of the Drawing Board." *Montana: The Magazine of Western History,* Summer 1969, 38-48.

Likely Sources Not Yet Investigated

Stone and Webster was purchased by the Shaw Group in 2000 and is currently based in Stoughton, Massachusetts. If a Stone and Webster corporate archive exists, it is possible that it might yield additional information on the 1911-1913 period of construction at Powerhouse 1. Arthur Kelley's *Valuation*, however, notes that a thorough search of Stone and Webster's archives in Boston, Seattle, and southern California in 1922 failed to discover the original cost accounting documents from Big Creek.